COMMONWEALTH OF PENNSYLVANIA.

DEPARTMENT OF AGRICULTURE.

BULLETIN NO. 104

Modern Dairy Science and Practice,

BY

LUCIUS L. VAN SLYKE, PH. D.

Chemist, New York Agricultural Experiment Station, Geneva, N. Y.

PUBLISHED BY DIRECTION OF THE SECRETARY.

1902.

WM. STANLEY RAY,
STATE PRINTER OF PENNSYLVANIA.
1903.

VIRTUE
LIBERTY AND
INDEPENDENCE

PREFACE.

Harrisburg, Pa., September 3, 1902.

The following Bulletin, No. 104, upon "Modern Dairy Science and Practice," by Lucius L. Van Slyke, Ph. D., Chemist of the New York Agricultural Experiment Station, is issued by this Department for the purpose of aiding our dairymen in their efforts to understand the scientific facts that underlie dairy production. Dr. Van Slyke is an acknowledged authority upon dairy science and practice; his statements and recommendations, therefore, can be relied upon as being the latest and best information upon this subject.

JOHN HAMILTON,
Secretary of Agriculture.

LETTER OF TRANSMITTAL.

Hon. John Hamilton, *Secretary of Agriculture, Harrisburg, Pa.*

Dear Sir: I have the honor to transmit herewith a bulletin, entitled "Modern Dairy Science and Practice," which has been prepared in compliance with your request and in accordance with suggestions approved by you.

Respectfully yours,

LUCIUS L. VAN SLYKE, Ph. D.,

Chemist, New York Agricultural Experiment Station.

Geneva, N. Y., Sept. 3, 1902.

TABLE OF CONTENTS.

INTRODUCTION.

CHAPTER I.

THE CHEMISTRY OF MILK.

1. General Composition of Milk. 2. Water. (1) Chemistry. (2) Purpose. (3) Amount in milk. (a) Single milkings. (b) Lactation period. (c) Herds. (d) Breed. (e) Advance of lactation. (f) Age. 3. Glycerine-fat or butter-fat. (1) A mixture. (2) Melting points of constituents. (3) Glycerine. (4) Physical properties. (5) Fat-globules. (6) Amount in milk. (a) Individuality. (b) Breed. (c) Age. (d) Time between milkings. (f) Relation of yield to fat. (g) Influence of food. (h) Different portions of milkings. 4. Nitrogen compound of milk. (1) Number of proteids in milk. (2) Milk-casein. (a) Milk-casein not in solution. (b) Composition. (c) Action of acids. (d) Alkalies. (e) Other compounds. (f) Heat. (g) Rennet. (3) Milk albumin. (4) Galactase. (5) Amount of casein and albumin. 5. Milk-sugar. 6. Salts of milk. 7. Gases of milk. Pages, ... 10-20.

CHAPTER II.

CONTAMINATION OF MILK.

8. What is fermentation? 9. Two classes of ferments. (1) Organized. (2) Unorganized ferments or enzymes. 10. Sources of bacteria in milk. (1) Dairy utensils. (2) Udder cavity. (3) Bodies of cows. (4) Milkers. (5) Air of stable. 11. Other sources of contamination. 12. Kinds of bacteria in milk. (1) Lactic acid fermentation or souring of milk. (2) Fermentations affecting milk-casein. (3) Butyric acid or "rancid" fermentations. (4) Less common fermentations. (5) Disease germs in milk. Pages, ... 21-27.

CHAPTER III.

PREPARATION OF MILK FOR MARKET.

13. Keeping bacteria out of milk. (1) Stable. (2) Body of cow. (3) Milker. (4) Dairy utensils. (5) Time of feeding. (6) Diseased milk. (7) Contagious diseases. (8) Removal from stable and subsequent treatment. 14. Preventing or delaying growth of bacteria. 15. Destroying bacteria in milk. (1) Pasteurizing milk. (2) Sterilizing milk. Pages, ...27-31.

CHAPTER IV.

CREAM.

16. Composition of cream. 17. Separation of cream. 18. Gravity method of cream separation. (1) Shallow-pan system. (2) Deep-setting system. 19. Separation of cream by centrifugal force. (1) Conditions affecting creaming effici-

ency of separators. (a) Intensity of centrifugal force. (b) Rate of inflow of milk. (c) Temperature of milk. (2) Regulating richness of cream. (3) Creaming efficiency of separators. (4) Promptness in separating milk. (5) Advantages of creaming by centrifugal force. (a) Saving of fat. (b) Control of quality of cream. (c) Freedom from dirt. (d) Skim-milk sweet. 20. Artificial thickening of pasteurized cream. 21. Profits derived from selling cream. 22. Composition of skim-milk. (1) Difference between separator and gravity skim-milk. (2) Difference in skim-milk from different kinds of milk. 23. Valuable uses of skim-milk. 24. Composition of separator slime. Pages, ... 32-40.

CHAPTER V.

BUTTER-MAKING.

25. Composition of butter. 26. Ripening cream for butter-making. 27. Production of lactic acid in cream ripening. (1) Natural starters. (2) Pure culture starters. 28. Amount of acid needed for cream ripening. 29. Effects produced by cream ripening. (1) Improved flavor of butter. (2) Ease of churning. (3) Increased yield of butter. (4) Better-keeping quality of butter. (5) Greater uniformity of quality. 30. Mixing cream of different ages. 31. Pasteurizing cream for butter-making. 32. Richness of cream for butter-making. 33. Conditions affecting churning. (1) Composition and size of fat-globules. (2) Composition of milk serum. (3) Degree of ripeness of cream. (4) Temperature used in churning. (a) Individuality of cows. (b) Stage of lactation. (c) Character of food. (d) Season of year. (e) Richness of cream. (f) Degree of ripeness. (5) Kind of churn. 34. When to stop churning. (1) Completeness of churning. (2) Buttermilk in butter. 35. Difficulties in churning. (1) Advanced lactation. (2) Improper cream ripening. (3) Cream poor in fat. (4) Low temperature in churning. 36. Removing buttermilk from granules. (1) Percentage of water in butter. (2) Washing and texture of butter. 37. Working butter. 38. Salting butter. 39. Packing butter. 40. Qualities of butter. (1) Flavor. (2) Texture. (3) Color. (4) Salt. (5) General appearance. (6) Moisture. (7) Solidity. 41. Composition of buttermilk. Pages, ... 40-57.

CHAPTER VI.

THE RELATION OF MILK TO YIELD OF BUTTER.

42. Distribution of milk-fat in butter-making. 43. Relation of fat in milk to yield of butter. 44. How to detect losses by yield of butter. 45. Milk-fat as a basis of paying for milk at creameries. 46. Calculating dividends at creameries on basis of milk-fat. (1) In co-operative creameries. (2) In creameries where milk is purchased. Pages, ... 57-62.

CHAPTER VII.

PRELIMINARIES OF CHEESE-MAKING.

47. Care of milk for cheese-making. (1) Cooling milk. (2) Aerating milk. 48. Detection of injurious fermentations in milk. 49. Source and properties of rennet extract. (1) Source of rennet extract. (2) Strength of rennet in coagulating milk. (3) Chemical action of rennet. (4) Conditions of rennet action. (a) Acids. (b) Temperature. (c) Strength of rennet extract. (d) Effect of acid salts, alkalies, disinfectants, etc. (e) Heat. (f) Different milks. 50. Methods of testing rennet extract. (1) Monrad test. (2) Marschall test. 51. Ripening milk for cheese-making. (1) How to ripen milk. (2) How to determine the degree of ripeness. Pages, ... 63.69.

CHAPTER VIII.

MAKING CHEDDAR CHEESE.

52. Coagulating milk by rennet extract. (1) Temperature of milk for coagulation. (2) Amount of rennet to use. (3) Method of adding rennet. 53. Cutting curd. (1) When. (2) How. 54. Heating the curd. 55. Removing whey from curd. 56. Cheddaring the curd. (1) Matting curd on vat bottom. (2) Matting curd on curd-rack in vat. (3) Matting curd in curd-sink. 57. Milling the curd. 58. Salting and pressing curd. 59. Some common troubles of cheese-making. (1) Gas-forming fermentations. (2) Overripe milk. 60. Sizes of cheese. Pages, 69-78.

CHAPTER IX.

CURING CHEESE—QUALITIES OF CHEESE.

61. Changes caused by curing cheese. (1) Loss of moisture. (a) Original moisture in cheese. (b) Texture of cheese. (c) Size and shape of cheese. (d) Temperature of curing-room. (e) Proportion of water vapor. (2) Changes in paracasein compounds. 62. Temperature for curing cheese. 63. Moisture in air for curing cheese. 64. How to control moisture and temperature in cheese-curing rooms. (1) Location of curing-rooms. (2) Windows. (3) Door. (4) Walls. (5) Ceiling and floor. (6) Ventilating flue in ceiling. (7) Controlling temperature and moisture. (a) Sub-earth ducts. (b) Ventilating over ice. (c) Evaporation of water. 65. Qualities of cheese. (1) Flavor. (2) Body. (3) Texture. (4) Color. (5) General appearance. Pages, ... 79-88.

CHAPTER X.

THE RELATIONS OF MILK TO CHEESE.

66. Relations of composition of milk to yield of cheese. (1) Amount of milk-fat lost in cheese-making. (2) Amount of casein in different milks. (3) Increase of cheese yield with increase of fat in milk. 67. Losses of milk constituents in cheese-making. (1) Cheese-producing and whey-producing solids in milk. (2) Loss of milk-fat in cheese-making. (3) Loss of milk casein in cheese-making. 68. Relation of composition of milk to composition of cheese. (1) In normal milk. (2) In skim-milk. (3) In milk containing added cream. 69. Composition of milk in relation to quality of cheese. 70. Standard of composition for whole-milk cheese. 71. Methods of paying for milk at cheese factories. 72. Calculating dividends on milk-fat basis at cheese factories. 73. Composition of whey. 74. Composition of cheese. 75. The value of cheese as food. (1) Concentrated food. (2) Cheap. (3) Rich in protein. Pages, ... 88-99

CHAPTER XI.

METHODS OF TESTING MILK AND ITS PRODUCTS.

76. Need of tests. 77. The Babcock test. 78. Advantages and disadvantages. 79. Description of apparatus and materials used in Babcock test. (1) Test bottles. (2) Pipette for measuring. (3) Measure for acid. (4) Centrifugal machine. (5) Commercial sulphuric acid. 80. How to sample milk for testing. (1) Conditions making sampling difficult. (2) Taking samples. 81. Running sample into bottle. 82. Adding acid to milk. (1) Strength of acid. (2) Caution in handling acid. (3) Measuring acid and adding to milk. (4) Mixing acid and milk. 83. Whirling test bottles. 84. Measuring amount of fat. 85. Testing

cream by Babcock test. 86. Testing skim-milk, buttermilk and whey. 87. Testing condensed milk. 88. Testing cheese. 89. Taking composite samples at creameries and cheese factories. 90. Testing acidity of milk and cream. (1) General principles of test. (2) Mann's acid test. (3) Farrington's alkaline tablet-test. 91. The use of lactometers in testing milk. (1) The specific gravity of milk. (2) The Quevenne lactometer. (3) The Board of Health lactometer. (4) Value of lactometer in detecting adulterated milk. (5) Use of lactometer in estimating solids in milk. Pages, ... 99-115.

CHAPTER XII.

SPECIAL DAIRY PRODUCTS.

92. Special milk preparations. (1) Blended milk. (2) Modified milk. (3) Condensed milk. 93. Special varieties of cheese. (1) Cottage cheese. (2) Potted cheese, or club cheese. 94. Special dairy beverages—Koumiss. Pages, ..115-119

MODERN DAIRY SCIENCE AND PRACTICE.

By L. L. Van Slyke, Ph.D., Geneva, N. Y.

INTRODUCTION.

Dairying has for its objects the production of milk and the manufacture of various food products from milk. Dairying may, therefore, be divided into two fairly distinct departments: Dairying (1) as a branch of agriculture, and (2) as a manufacturing industry.

Considered as the source of milk production, dairying is a branch of agriculture; for the producer of milk tills the soil, raises food crops for the cattle, rears dairy animals, and obtains milk as his finished product. He is a manufacturer, employing agricultural methods. Considered as a source of cream, butter, cheese, etc., dairying is a manufacturing industry. The maker of butter and cheese starts with milk as his raw material and employs methods that are essentially industrial and in no way connected with agriculture proper. While these two departments of dairying have in the past been carried on largely side by side on the farm, the modern tendency has been toward a more complete separation. Attention is here called to these two divisions of dairying, because it is the writer's purpose in this treatise to dwell almost entirely upon the second division. To attempt to cover the field of dairying in its broadest sense would practically involve consideration of a large portion of the broad domain of agriculture.

Dairying is both an art and a science, whether considered in its restricted or broad sense.

The art or practice of dairying embraces certain practices and processes which have been gradually developed by experience and observation. The art of dairying, in its widest application, teaches how to cultivate the soil for the production of certain crops; how to make and use fertilizers; how to breed, feed and care for dairy animals for the production of milk; how to produce cream, butter, cheese, etc., from milk.

The science of dairying embraces a collection of the general principles or leading truths, arranged in systematic order, relating to the operations of dairying. Thus, among other things, the science of dairying explains the growth of animals, the relation of foods to milk production, the chemical composition and physical properties of milk and its products. It consists of an application of the truths of such sciences as physiology, chemistry, physics, botany, etc., to the practical operations of dairying.

Dairying has undergone many profound changes during the last generation, and more particularly during the last fifteen years. This is true of both the agricultural and the manufacturing phases of dairying. We can fully realize this by noticing the changes in its very language. Even ten years ago few dairymen would have been able to use intelligently, if at all, many of the expressions that are very common now, such as bacteria, lactic acid fermentation, pasteurization, sterilization, separator cream, ripened cream, fat basis for paying dividends, ripening tests, etc., etc. With all the advance in knowledge and the improvement in practice that we have witnessed in recent times, there are still many unsolved problems in dairying; but we do well to be impressed with the great things which have already been accomplished and to appreciate the advantageous position we are now in for making further progress, compared with the position we were in only fifteen years ago.

These changes for the better have been brought about through the combination of a variety of educational agencies, among which may be mentioned our agricultural experiment stations, dairy schools, State Departments of Agriculture, farmers' institutes, the agricultural press, farmers' clubs, etc.

Our dairy products, as a result of improved methods of producing milk and of improvement in manufacturing processes, are greatly superior on the average to those we made half a generation ago. The consuming public has, to some extent, become more choice in its tastes and exacting in its demands; in other words, the present standards required for dairy products are higher than they were.

The object of this little treatise is to present, with a moderate degree of fullness, some of the results of these recent years of progress, so as to give the reader some idea of what constitutes "Modern Dairy Science and Practice."

CHAPTER I.

THE CHEMISTRY OF MILK.

1. General Composition of Milk.

In milk, as well as in most of its commercial products, we find the following compounds and classes of compounds:

(1) Water.
(2) Fat.
(3) Nitrogen compounds or proteids.
(4) Sugar.
(5) Salts or ash
(6) Gases.

In giving the description of any individual chemical compound in connection with the chemistry of milk, we shall not need to repeat the description when we come to consider that compound in connection with the products of milk; for, it will be found, the description given here will apply to the same compound wherever we find it. The word milk, as we shall use it, refers always to cows' milk, unless otherwise stated.

2. Water.

1. Chemistry.—The water present in milk and its products, however much its presence may be disguised, is one and the same compound of hydrogen and oxygen, with which we are everywhere familiar. The water in milk and its products is simply plain, common water, possessing no chemical peculiarities to distinguish it from water found anywhere else. It is only ordinary water in the company of other chemical individuals.

(2.) Purpose.—The water in milk serves the purpose of holding in solution the soluble constituents of the milk. It also acts as a diluent, better fitting the mixture as animal nutriment.

(3.) Amount of Water in Milk.—The amount of water contained in milk varies considerably, depending upon a variety of conditions, such as individuality, breed, stage of lactation, age, character of food, amount of water drunk, condition of health, etc.

(a.) Single Milkings.—Taking single milkings of individual cows, we may find the amount of water in 100 pounds of milk varying from 82 to 90 pounds or more, corresponding to 10 to 18 pounds of total solids.

(b.) Lactation Period of Single Cows.—In case of milk from single cows for an entire period of lactation, the variation of water may range from 84 to 89 pounds, corresponding to 11 to 16 pounds of total solids.

(c.) Herds.—Taking milk from herds of cows, the variations of water are within narrower limits, usually ranging from 86 to 88 pounds in 100 pounds of milk, corresponding to 12 to 14 pounds of total solids.

In the case of average milk, as found in the United States, 100 pounds of milk contain from 87 to 87 1-4 pounds of water, corresponding to 12 3-4 to 13 pounds of solids.

(d.) Breed.—As regards the influence of breed of cow upon the proportion of water in milk, the following figures, taken from the Geneva (N. Y.) Station records, serve as a fair illustration:

Name of Breed.	Lbs. of water in 100 lbs. of milk.	Lbs. of total solids in 100 lbs. of milk.
Holstein,	88.20	11.80
American-Holderness,	87.35	12.65
Ayrshire,	87.25	12.75
Shorthorn,	85.70	14.30
Devon,	85.50	14.50
Guernsey,	85.10	14.90
Jersey,	84.60	15.40

(e.) Advance of Lactation Period.—The following figures, showing the variation of water in milk with advance of lactation of period, are based upon averages derived from an aggregate of nearly fifty lactation periods of individual cows, covering the first ten months of lactation:

Month of Lactation.	Lbs. of water in 100 lbs. of milk.	Lbs. of total solids in 100 lbs. of milk.
1,	86.00	14.00
2,	86.50	13.50
3,	86.53	13.47
4,	86.36	13.64
5,	86.25	13.75
6,	86.00	14.00
7,	85.82	14.18
8,	85.67	14.33
9,	85.54	14.46
10,	85.17	14.83

We notice a general tendency for the water to increase for three months, after which there is a constant decrease to the end of the lactation period. A similar tendency is shown in the illustration given below, which covers a large number of samples of milk obtained from cheese factories, representing practically the first six months of the lactation period.

Month.	Lbs. of water in 100 lbs. of milk.	Lbs. of total solids in 100 lbs. of milk.
May,	87.44	12.56
June,	87.31	12.69
July,	87.52	12.48
August,	87.37	12.63
September,	87.00	13.00
October,	86.55	13.45

(f.) Age. There are not available many data giving reliable information in respect to the influence of the age of a cow upon the amount of water in milk. There is more or less variation in different individuals. From the limited amount of data accessible, there appears to be a general tendency for cows to produce milk with least water during the second period of lactation, after which the amount of water in the milk increases with the age of the animal.

3. Milk-Fat (or Butter-Fat).

1. Milk-Fat a Mixture.—Milk-fat is not a single, invariable compound, but is a somewhat variable mixture of several different compounds, each of which contains the elements carbon, hydrogen and oxygen, combined in different proportions. Each of these separate compounds, contained in milk-fat, is formd by the chemical union of glycerin with some acid of a particular kind. These glycerin-acid compounds contain about ten different acids, but some of them are present in very small quantities; in fact, 90 per cent. of milk-fat is made up of only four of these compounds. We can, in a general way, represent the composition of these four most important glycerin-acid compounds of milk-fat in the following manner:

Glycerin and palmitic acid form palmitin.
Glycerin and oleic acid form olein.
Glycerin and myristic acid form myristin.
Glycerin and butyric acid form butyrin.

These four compounds are present in milk-fat (or butter-fat) in something like the following amounts:

Palmitin, 40.5 per cent.
Olein, 34.0 per cent.
Myristin, 10.5 per cent.
Butyrin, 6.2 per cent.

The proportions of these constituents of milk-fat vary somewhat and this variation influences the character of the milk-fat.

(2.) Melting Points of Constituents of Milk-Fat.—In order to understand more fully some of the properties of milk-fat, we will briefly notice some of the more important properties of the above-mentioned compounds.

Palmitin has a rather high melting point, 144 degrees F.

Myristin melts at 129 degrees F.

Olein and butyrin are liquid at ordinary temperatures. Olein has the important property of being able to dissolve and hold in solution the less easily melting palmitin and myristin, above certain temperatures.

Palmitin and myristin tend to produce hardness in butter; olein and butyrin, softness.

(3.) Glycerin is present, chemically combined with acids, in all fats. It forms, on an average, about 12.5 per cent. of pure milk-fat or butter-fat.

(4.) Physical Properties of Milk-Fat.—Milk-fat, in pure, fresh condition, appears at ordinary temperatures as a soft, white to yellowish mass, with mild taste and very slight odor. It easily takes on a granular structure. It melts easily and is lighter than water.

Our knowledge of the color of milk-fat is very limited. Whether the color is a property of some one of the compounds of milk-fat, or whether it belongs to some special substance, mechanically held by the milk-fat, we can not say positively, but the latter supposition is probably nearer the truth. It is well established that the color of milk-fat varies with individual cases, with breeds, with advance of lactation and with the food.

(5.) Milk-Fat in Form of Globules.—Milk-fat is present in milk in the form of very small, transparent globules, too small to be seen by the unaided eye. The sizes most commonly met with are between 1-2500 and 1-15000 of an inch in diameter, and the average diameter is not far from 1-10000 of an inch. Some globules are as large as 1-1500 of an inch and some as small as 1-40000 of an inch. The smaller fat-globules are more numerous than the larger ones. In one drop of average milk there are about 150,000,000 fat globules.

Formerly it was very generally believed, and is still held by some, that fat-globules of milk are surrounded by a membranous covering. In some respects, fat globules behave as if they were enclosed in a membrane. The theory also has been advanced that the fat-globules are surrounded by a semi-solid membrane of slime. Without going into details to state the reasons, we may accept it as established beyond reasonable doubt that fat-globules have no special covering, but are simply minute particles of fat floating free in

milk in the form of an emulsion. There is no difference in the composition of the fat in the large and small globules.

(6.) Amount of Fat in Milk.—The amount of fat present in normal milk varies greatly, going, in the case of single milkings of individual cows, below 2 per cent. and above 10 per cent. The average of fat in the milk of herds of cows varies commonly between the limits of 3 and 5 per cent. The average amount of milk-fat in milk produced in the United States, taking the true average for an entire year, lies between 3.75 and 4 per cent., and somewhat nearer the latter figure.

Many of the conditions that affect the amount of fat in milk have been studied and are well established, while others are but little understood. We will consider briefly some of the better-known conditions.

(a.) Individuality.—It is uncommon to find in a herd of cows any two individuals whose milk contains the same per cent. of fat, whether we consider individual milkings or the average of many milkings. This is simply one of many factors that go to make a cow's individuality.

(b.) Breed.—It is well known that the per cent. of fat in milk varies in a more or less characteristic way with the kind of breed. While there is marked variation in indivduals of the same breed, there is found to be a fairly uniform difference, more or less marked, if we take the average of several individuals. It is largely owing to this influence that we find the milk of one country differing from that of another, or the milk of one section of a country differing from that of another section. For example, the average per cent. of fat in milk in Germany and Holland is fully one-half per cent. lower than in this country, because the prevailing breeds of cows there are the ones producing milk comparatively low in fat. The figures given in the following table are taken from the records of the Geneva (N. Y.) Station and represent averages of several individuals covering several periods of lactation:

Name of Breed.	Per Cent. of Fat in Milk.		
	Average.	Lowest.	Highest.
Holstein,	3.36	2.88	3.85
Ayrshire,	3.60	3.20	4.24
American-Holderness,	3.73	3.49	3.92
Short-Horn,	4.44	4.28	4.56
Devon,	4.60	4.30	5.23
Guernsey,	5.30	4.51	6.13
Jersey,	5.60	4.96	6.09

(c.) Age.—So far as published data throw light upon the question of the influence of age upon the amount of fat in milk, the more common tendency appears to be for milk to become less rich in fat with each succeeding period of lactation, especially after the second, though individual exceptions to this tendency are not infrequent. We need more extended data bearing upon this point before we can speak with any degree of positiveness.

(d.) Advance of Lactation Period.—In general, it is found that the per cent. of fat in milk increases as the stage of lactation advances. The following figures represent the averages obtained from an aggregate of nearly fifty lactation periods of different cows, covering a period of ten months:

Number of Month of Lactation.	Per cent. of fat in milk.
First,	4.54
Second,	4.33
Third,	4.28
Fourth,	4.39
Fifth,	4.38
Sixth,	4.53
Seventh,	4.56
Eighth,	4.66
Ninth,	4.79
Tenth,	5.00

(e.) Variation of Time Between Milkings.—As a rule, the longer the time between two successive milkings, the smaller is the per cent. of fat in the milk, and the shorter the time between milkings, the greater the per cent. of fat. When the time between milkings is uniformly equal, the variation of fat in milk is small, provided the general conditions surrounding the cow are the same. However, as there is not commonly such entirely uniform condition of surroundings during the day and night, there is probably a common tendency in the direction of a little more fat in the morning's milk.

(f.) Relation of Yield of Milk to Fat.—Large yields of milk are usually, though not necessarily, accompanied by lower percentages of milk-fat, while smaller yields are more commonly associated with larger percentages of fat.

(g.) Influence of Food Upon Amount of Fat in Milk.—This question has been the subject of investigation for years, but we are not yet able to say that we can "feed fat into milk," under ordinary, normal, practicable conditions. It has been noticed by several investigators that a very marked change in the general character

of food, as from an insufficient amount of dry hay to an abundance of nutritious, succulent food, is accompanied by an increase in the percentage of fat in milk, as well as in the yield of milk.

The writer has noticed that, in the case of milk taken to cheese factories, the fat increased very noticeably and generally during the latter half of May, as compared with the preceding portion of the month. In these cases, the cows were commonly fed on timothy hay, without grain, until pasturage came. There was thus a very marked change in the character of the food. However, we cannot deny that the more favorable surroundings of the cows at pasture, as compared with the cows kept in the stable or yard, exerted an influence that should not be overlooked. Taking the milk of quite a large number of different cheese factories we found, on an average, during the first half of May, the per cent. of fat was 3.46, and during the latter half 3.70, an increase of 0.24 per cent. in a brief space of time.

(h.) Variation of Fat in Different Portions of Milk Drawn from Udder.—In the case of the figures given below, the udder was milked as nearly as possible in four equal portions.

	First cow—Per cent. of fat in milk.	Second cow—Per cent. of fat in milk.	Third cow—Per cent. of fat in milk.
First portion,	0.90	1.60	1.60
Second portion,	2.60	3.20	3.25
Third portion,	5.35	4.10	5.00
Fourth portion,	9.80	8.10	8.30

It is seen that in every case the first fourth of the milk drawn from the udder is very low in fat, and that the fat increases in successive portions drawn, until in the last it is extremely high. The most satisfactory explanation offered for this behavior of fat in milking is that the fat-globules strike against the sides of the minute ducts, through which they flow, and the friction thus caused holds the globules back, the milk that remains in the ducts becoming increasingly richer in fat in consequence.

4. The Nitrogen Compounds or Proteids of Milk.

(1.) Number of Proteids in Milk.—So far as our present knowledge goes, we appear to be justified in believingthat milk contains not more than four nitrogen compounds or proteid bodies, and these are:

Casein,
Albumin,
Globulin,
Galactase.

Globulin and galactase are present in so small quantities that we can regard casein and albumin as being essentially the nitrogen compounds of milk. These bodies are called nitrogen compounds, because they contain, in addition to other elements, the very important element called nitrogen. These nitrogen compounds of milk or milk proteids can be formed only from proteids received by the cow in the food.

(2.) Milk-Casein.—This is the most important proteid in milk, because it is the one present in largest quantity and also because its presence makes it possible to convert milk into cheese. Milk-casein is most familiar to us in the form of the white, solid substance, or curd formed in milk when it sours, though, strictly speaking, this white substance is not milk-casein but a compound formed by it with acid.

(a.) Casein in Milk Not in Solution.—For a long time it was thought that casein was in true solution in milk; but evidence, produced by different lines of investigation, show beyond question that casein exists in milk in the form of minute, solid, gelatinous particles in suspension. Casein forms a considerable part of separator slime.

(b.) Composition of Casein.—Casein is a very complex chemical compound, containing the elements of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. It is believed that calcium (or lime) compounds are in some way combined with casein.

(c.) Action of Acids on Casein.—Very dilute acids completely coagulate or solidify the casein of milk. In this action the acid forms a compound with casein. If a large amount of acid is added to milk, the casein is first coagulated and then dissolved, as in the case of adding sulphuric acid to milk in the Babcock test bottles. The action of acids in coagulating milk-casein is hastened by increase of temperature.

(d.) Action of Alkalies on Casein.—Such compounds as caustic soda and potash, ammonia, sodium and potassium carbonate, unite with casein and form compounds that are easily soluble in water. They also dissolve the casein that has been coagulated. Some of these compounds are found in commerce as food preparations. Nutrose is a food preparation that consists mostly of sodium casein.

(e.) Action of Other Compounds on Milk Casein.—Certain chemical compounds, when added to milk in large quantities, coagulate casein, such as common salt, magnesium sulphate (Epsom salt), ammonium sulphate, etc. Other compounds, added in smaller quantities, coagulate casein, such as alum, zinc sulphate, corrosive sublimate, formalin, etc.

(f.) Action of Heat on Casein.—Heat alone under ordinary conditions, even at boiling point, does not coagulate casein in milk. The formation of a peculiar skin on the surface of milk heated above 140 degrees F., is largely due to the casein of the milk, and not to albumin, as was formerly supposed. The skin itself contains practically all the constituents of milk and is a kind of evaporated milk.

(g.) Action of Rennet on Milk-Casein.—One of the most characteristic properties of milk-casein is its coagulation by rennet, this property making it possible to manufacture cheese from milk. The curd formed by action of rennet is a compound different from casein and is called paracasein. The coagulation of casein by rennet is quite different from that produced by acids. In connection with the subject of cheese-making, we will consider in detail the properties of rennet and the conditions that affect its power to coagulate with milk-casein.

(3.) Milk-Albumin.—Milk-albumin differs from milk-casein in many ways, the most important of which we will briefly notice. First, milk-albumin is not acted on by rennet; second, it is not coagulated by acids at ordinary temperatures; third, it is coagulated by heat alone, though not completely, above 160 degrees F. From these characteristic differences, it can readily be seen that casein and albumin are very different compounds.

(4.) Galactase in milk was discovered by Drs. Babcock and Russell about five years ago. It is present in very small amounts. It has the power of acting upon milk-casein, first changing it into a solid and then dissolving it. It is believed to be active in cheese ripening.

(5.) Amount of Casein and Albumin in Milk.—In general, the amount of casein and albumin, taken together, are found in milk in quantities ranging from 2.50 to 6 per cent.; the average is about 3.2 per cent. There is about 3.5 times as much casein as there is albumin.

(a.) Casein.—Casein in milk varies from 2 to 4 per cent., and averages 2.50 per cent.

(b.) Albumin.—Albumin in milk varies from 0.50 to 0.90 per cent., and averages 0.70 per cent.

(c.) Influence of Lactation on Casein and Albumin.—There is a very general tendency for casein and albumin to increase in milk as the period of lactation advances, and somewhat more rapidly in proportion than the milk-fat.

5. Milk Sugar.

Milk-sugar is present in cows' milk in solution. In general composition it resembles our ordinary sugar, but its sweetness is very much less than that of cane sugar, and it is also less readily soluble

in water. It is present in milk in amounts varying from 4.5 to 5.5 per cent., and averaging 5 per cent. Its importance in dairy manufacture, especially in connection with butter and cheese, comes from the readiness with which it is converted into lactic acid by various organisms. This action will be studied in detail in the next chapter.

6. The Salts of Milk (or Ash).

The salts of milk, also called the mineral matter, or ash, are important constituents, though they are present in only small quantities, varying from 0.50 to 0.90 per cent., and averaging about 0.70 per cent., as expressed by the ash. The elements which go to make up the salts of milk, stated in the order of their abundance, are the following: Phosphorus, potassium, calcium, chlorine, sodium, magnesium, sulphur and iron. The calcium is probably present in the form of calcium phosphates; the sodium, as sodium chloride; the potassium, as potassium phosphate, chloride and citrate.

7. The Gases of Milk.

Milk contains more or less oxygen and nitrogen, some portions of these gases being carried into it mechanically from the air in the process of milking. It contains also carbon dioxide when freshly drawn, probably between 3 and 4 per cent., a portion of which escapes at once while being milked under usual conditions.

We have now seen, in some detail, how many and what different compounds are contained in milk. There are certain arbitrary divisions of these compounds made for the sake of convenience. One such division makes two classes of the compounds of milk—(1) water and (2) solids, or milk-solids, or total solids, these including fat, casein, albumin, milk-sugar and salts, or ash, of milk. Another division is on the basis of the milk-fat, into (1) fat and (2) milk-serum, this including all the milk except the fat, that is, water, casein, albumin, milk-sugar and ash. Separator skim-milk is nearly pure milk serum. Then, again, the milk-solids themselves are divided into (1) fat and (2) solids-not-fat, the solids-not-fat including the milk serum less the water.

Analyses of Milk.

	Per cent. of water.	Per cent. of total solids.	Per cent. of fat.	Per cent. of casein.	Per cent. of albumin.	Per cent. of sugar.	Per cent. of ash.
Average of 5,552 American analyses compiled by the writer,	87.10	12.90	3.90	2.50	0.70	5.10	0.70
Average cheese-factory milk for the season (May to November) in New York State,..	87.40	12.60	3.75	2.45	0.70	5.00	0.70

CHAPTER II.

CONTAMINATION OF MILK.

Milk, on standing, undergoes a variety of changes sooner or later, many of which spoil it for use as food. The most common and extensive changes occurring in milk are due to fermentations. One result of some fermentations is the production of bad flavors, but these may be acquired also either by direct absorption from the surrounding air or from the food consumed. To these different sources of contamination we will now give some detailed attention.

8. What is Fermentation?

The meaning of fermentation can best be made clear by illustration. When a fruit juice, like sweet cider, is allowed to stand at ordinary temperature, it soon begins to undergo changes, large quantities of bubbles of carbon dioxide gas come from the surface of the liquid, and some alcohol is formed. In this case, the sugar of the apple juice is changed into alcohol and carbon dioxide. If this cider, containing alcohol, is allowed to stand long enough at ordinary temperatures, the alcohol disappears, being changed into acetic acid and we then have what we commonly call cider vinegar. The process resulting in the change of the sugar in the cider into alcohol and carbon dioxide is called a fermentation; and that resulting in the change of alcohol into acetic acid or vinegar is also a fermentation.

When milk is freshly drawn, it is sweet, but, on standing a while at ordinary temperature, it becomes sour. The change taking place is the formation of lactic acid from milk sugar, and it is caused by certain germs. The souring of milk is another case of a fermentation.

That which causes fermentation is called a ferment. As there are many different kinds of fermentation, so there are many different kinds of ferments. In the production of alcohol and carbon dioxide from the sugar in cider, the ferment is yeast; in the fermentation of vinegar from alcohol, certain kinds of bacteria are the ferment in the conversion of milk sugar into lactic acid, certain other bacteria constitute the ferment.

Ferments possess certain general characteristics in common, among which may be mentioned the following: (a) A very small amount of

ferment is capable of producing very great changes. (b) They are all dependent upon temperature as a condition of activity. They cease to act at low and also at high temperatures. Most of them find the temperature best suited to their greatest activity between 80 and 100 degrees F. (c.) Ferments are destroyed by heat, the temperature of boiling water in most cases completely destroying their power to act. Their activity is checked by low temperatures, but, when again warmed, they renew their activity. (d.) The products which ferments form, when accumulating in certain amounts, usually stop further action. (e.) All ferments are closely connected with life processes.

9. Two General Classes of Ferments.

The different bodies that are capable of causing fermentations may be divided into two general classes (1) organized ferments, and (2) unorganized ferments.

(1.) Organized Ferments are living organisms capable of producing fermentations. Those of greatest interest found in milk and its products are called bacteria. Bacteria are the smallest conceivable forms of plant life. Each individual consists of a single cell, averaging in diameter one-thirty thousandth of an inch. They appear in three general varieties of form: Ball (coccus), short rod (bacillus), and cork-screw (spirillum). They multiply in number or reproduce by simple division; that is, when a cell grows in size, it increases more in one direction, so as to lengthen out slightly, and a partition forms across the cell, thus producing two new cells in place of the old one; and then each of these subdivides again and so on continuously. Some kinds of bacteria form spores in the cells; these are to bacteria what seeds are to higher plants. Spores are not so easily killed by heat as are bacteria. Some bacteria have power of motion. Under favorable conditions, their rapidity of growth is remarkable. In some cases, one cell divides into two cells in twenty minutes; if this rate were kept up for twenty-four hours, the one cell would multiply into several millions. Bacteria require as food for satisfactory growth compounds containing nitrogen, carbon, hydrogen, and, in addition, small amounts of inorganic or mineral matter. The sugar, casein and albumin in milk and its products furnish a supply of food very readily utilized by bacteria. As already stated, bacteria are affected by temperature. The bacteria commonly present in milk grow between the limits of 40 and 110 degrees F., the most favorable temperatures being between 80 and 95 degrees F. Many bacteria are killed between 130 and 140 degrees F., when exposed to this degree of heat for ten minutes, and most are destroyed at 185 degrees F. Many spores are killed at temperatures con-

siderably above 212 degrees F., and even then require one to three hours. Dry heat is less effective than moist heat. Live steam, therefore, affords a most efficient means of destroying bacteria. All bacteria are rendered inactive by low temperatures and some may be killed by intense cold. Many bacteria may retain life even on being dried and become active again when placed under favorable conditions of moisture and temperature. Sunlight kills many bacteria when they are exposed directly to the sun's rays for a few hours. Bacteria are either checked in growth or killed by many chemical compounds. Those compounds that simply retard the rapidity of growth of bacteria are called antiseptics; those that destroy bacterial life are called disinfectants. Bacterial activity is stopped by an accumulation of the products formed by it and, in some cases, by the products of the activity of other bacteria. In the course of their growth, bacteria produce great changes in the materials in which they grow, and the processes by which these changes are brought about are known, as previously stated, under the general name of fermentations. Bacteria are found distributed nearly everywhere in the soil, in the air and in water. They are always present in large numbers wherever vegetable or animal matter is undergoing decay. They are, therefore, always closely associated with dirt and filth. While some are the cause of dreaded diseases, most of them are either harmless or actively helpful in many ways.

(2.) Unorganized Ferments or Enzymes are chemical substances or ferments, without life, capable of causing marked changes in many complex organic compounds, the enzymes themselves undergoing little or no change. Many enzymes are produced directly by bacteria, while many are formed in higher plants and in animals. The pepsin found in the human stomach is an enzyme; its special activity enables it to change proteid compounds from insoluble to soluble forms. The ptyalin contained in saliva is another enzyme, and is capable of changing starch into sugar. Babcock and Russell discovered in milk, a few years ago, an enzyme called galactase, which has the power of coagulating and then dissolving milk-casein. Another enzyme of interest in dairying is rennet, a small amount of which can coagulate many thousand times its own weight of milk. Enzymes are destroyed by high temperatures and by many disinfectants. Some substances, like ether and chloroform, do not seriously interfere with the activity of enzymes, while they do destroy bacterial activity.

10. Sources of Bacteria in Milk.

Milk, when drawn with careful precautions from the udder of a cow, contains comparatively few bacteria; but milk obtained and

handled under ordinary conditions, is found to contain large numbers, often several hundred thousand in one cubic centimeter (somewhat less than one-quarter of an ordinary teaspoonful). The more dirt there is in milk, the more bacteria there will be. Bacteria and dirt always go together in dairy matters. The bacteria found in milk come from the following sources:

(1) Dairy Utensils. Primarily the milk-pails, strainers and milk-cans. The cracks and joints of all utensils made of tin, unless great care in cleaning is used, contain dirt that holds large numbers of bacteria. Rust and imperfect soldering of joints furnish places for dirt to get out of easy reach. Without prompt and extreme care, strainers easily become filthy and are then simply breeding places for bacteria. When milk cans are used for carrying back to the farm from the cheese factory or creamery whey or skim-milk, the cans often are not cleaned promptly, and, when finally attended to, are not treated with proper thoroughness. Through the medium of a dirty skim-milk tank or whey-vat, filth germs of one form may be distributed throughout the whole neighborhood. Even epidemics of typhoid fever have been traced to this source of infection.

(2.) Udder Cavity.—The milk first drawn usually contains more bacteria than that drawn later. The end of the teat furnishes a good place for bacteria to grow, and some are able, sooner or later, to penetrate upward through the milk duct into the milk cistern and grow there to some extent. The first streams of milk drawn serve to wash out the lower portion of the milk cistern and the duct, and thus carry down bacteria in larger numbers than appear later.

(3.) Bodies of Cows.—The hair on cows favors the accumulation of dirt and dust. The condition is worse in proportion as cows are not regularly and thoroughly cleaned. Dust particles and hairs, laden with bacteria, are in position to drop into the milk pail. While the hairs and coarse chunks of dirt may be removed from milk by straining, the bacteria are, in large part, washed off into the milk and cannot be removed by any ordinary process of straining.

(4.) Milkers.—The hands and clothing of a milker may easily be loaded with bacteria and thus become a source of infection. Particularly objectionable is the filthy practice of some milkers of moistening the hands with milk.

(5.) Air of Stable.—A dirty condition of the floors, walls and ceilings of a stable all tend to contaminate milk. Any condition in the stable that affords a supply of floating dust at the time of milking furnishes additional bacteria for milk.

11. Sources of Contamination besides Bacteria.

While many of the undesirable flavors of milk are due directly to the result of bacterial action, milk may acquire taints that are not dependent on a bacterial origin. Milk, as it comes from a cow, possesses a peculiar "cowy" odor, due to direct absorption of volatile substances within the animal. This odor usually disappears quickly, when milk is exposed to the air; but it becomes abnormal in quality and persistence when a cow eats such things as leeks, turnips, cabbage, rag-weed, etc., a few hours before milking. If milk is not drawn for eight to twelve hours after such food is eaten, such taints either disappear or are greatly diminished. The same experience in milder form may come from the use of some green fodders, such as rape and green rye, and from the feeding of excessive quantities of swill, brewers' grains and distillery slops.

If milk, after being drawn, is exposed to contact with strong odors, such as those coming from manure or other decaying organic matter, or even from ensilage, it readily absorbs them. Milk, whether warm or cold, possesses a very striking power for absorbing and holding volatile odorous substances.

12. Kinds of Bacteria in Milk.

Many different kinds of bacteria have been found in milk. Some appear to be very generally present, others only rarely. Many of them have little or no appreciable effect upon milk or upon human beings; while some furnish products that are distinctly beneficial, others produce only injurious effects in milk, imparting to it bad flavors or unpleasant appearance, and, in some cases, even causing the formation of violent poison. It is also possible that the bacteria causing dread diseases may be found in milk in some instances. We present below the chief classes or types of bacteria that give rise to the fermentations most commonly occurring in milk.

(1.) Lactic Acid Fermentation or Souring of Milk.—The souring of milk is due to the formation of lactic acid, which is produced by the action of lactic acid bacteria upon the sugar in the milk. In this form of fermentation, one can begin to taste the acid when it amounts to about 0.3 per cent. of the milk. As the amount of acid increases to 0.4 per cent., the milk begins to curdle or thicken, and, as the amount of acid increases above this, the curd becomes more solid. These bacteria continue actively converting milk sugar into lactic acid until the acid reaches 0.8 to 1 per cent. of the milk, and then they cease their activity, because they cannot live in a solution containing this amount of acid. Their activity is stopped by the accumulation of the product of their own activity

and not because the supply of milk-sugar runs out, for, when they cease their activity, about three-quarters of the milk sugar still remains unconsumed. There are several different kinds of bacteria that can convert milk sugar into lactic acid. The temperature most favorable to the growth of lactic acid organisms is 90 degrees F. to 95 degrees F. Below 80 degrees F. they gradually lose their activity and practically cease at 50 degrees F. At 105 degrees F. they are fairly inactive, many are killed at 135 degrees F. to 140 degrees F., and at 150 degrees F. to 160 degrees F. all are killed. While this fermentation spoils milk for the taste of most people, it is a very essential factor in the manufacture of butter and cheese, as will be seen later. It is quite commonly thought that milk is peculiarly liable to sour during thunder storms, as the result of some peculiar electrical or other influence. The hot weather preceding such storms favors the more rapid growth of the lactic acid germs, and this is the proper explanation. Milk free from such germs never sours during thunder storms.

Some of the bacteria that act upon milk-sugar form large quantities of gases, especially carbon dioxide and hydrogen, and these gases are responsible in cheese-making for "floating" curds and "huffing" cheese.

(2.) Fermentations Affecting Milk-Casein.—Occasionally milk curdles without souring. This is caused by the action of rennet-like enzymes or ferments which certain bacteria produce. The same bacteria usually produce a second enzyme, which dissolves the coagulated casein. Some bacteria form only the dissolving or digesting enzyme, in which case the casein is slowly rendered soluble without previous coagulation. The bacteria that affect casein do not grow in the presence of lactic acid, and as the lactic acid bacteria usually develop more rapidly, they soon stop the growth of the former. In the absence of lactic acid bacteria, the digesting organisms are apt to grow. There are other forms of fermentation that act upon milk-casein and result in the production of substances having extremely offensive odors and disagreeable taste. In some cases poisonous products are formed, as, for example, tyrotoxicon, commonly known as cheese poison.

(3.) Butyric Acid, or "Rancid" Fermentations.—Some organisms act upon milk-fat or butter-fat, forming free butyric acid, thus producing the odor and taste of "rancid" butter. These bacteria grow slowly under ordinary conditions and do not commonly become active in milk, unless kept a long time, but they find their way into butter and, under favorable conditions, develop there to the disadvantage of the flavor of the butter.

(4.) Less Common Forms of Fermentation in Milk.—The kinds of bacteria described above are found commonly occurring in milk, but there are others which appear only occasionally, and some of these will now be briefly considered.

Most dairymen sometimes have milk that fails to sour or curdle, but after a few hours begins to be slimy and finally can be drawn out in long threads. This condition more commonly appears in cream. The trouble may be due to diseased udder, in which case it is apparent at once when the milk is drawn. The form which does not appear at once after milking is due to bacteria. Other abnormal forms of fermentation in milk result in producing alcohol, bitter milk, soapy flavor, fishy flavor, red, blue and other colors.

(5.) Disease Germs in Milk.—Milk furnishes a medium in which many disease germs can readily develop. Some disease-producing bacteria are capable of being transmitted directly from a diseased cow to a human being through the milk. It is quite generally believed that if milk is taken from a cow suffering with tuberculosis in the udder, it will be fairly sure to contain tuberculosis germs; and such milk taken into a human body may produce tuberculosis. Other disease-producing bacteria may get into the milk after it is drawn, having nothing whatever to do with the cow. Such are germs causing typhoid fever, scarlet fever, diphtheria and diarrhoeal diseases, such as cholera infantum. Such disease germs may get into milk from a case of illness on the premises where the cows are milked, through the carelessness and ignorance of the members of the household.

CHAPTER III.

PREPARATION OF MILK FOR MARKET.

In the preceding chapter we have seen that bacteria of different kinds get into the milk in various ways and, under conditions favorable to their activity, cause fermentations that may result in rendering milk totally unfit for sale. Therefore, the chief aim to be kept in mind in preparing milk directly for market is practically this, how to keep under control the growth of bacteria to such an extent that injurious fermentations shall not take place to any marked degree. Three general methods are in use for securing control of fermentations in milk: (1) Keeping bacteria from getting into milk, (2) preventing growth of bacteria already in milk, and (3) destroying bacteria already in milk. We will now consider these methods separately.

13. Keeping Bacteria from getting into Milk.

We have previously seen that the common sources which are responsible for furnishing the bacteria that are found in milk are (1) the air of the stable, (2) the body of the cow, (3) the person of the milker, and (4) the dairy utensils with which the milk comes into contact. We have also seen that the one common source of bacteria in all these cases is dirt. Hence, the one thing needful to prevent bacteria getting into milk is extreme cleanliness at every point of contact with the milk. The following suggestions are given to indicate what is meant by cleanliness in connection with milking and caring for milk.

(1.) The Stable.—Every condition about the stable should be regulated with reference to absence of dirt, an abundant supply of pure air, and a direct exposure to sunlight. The floors should be tight and of a material not readily absorbing liquids. An abundance of clean bedding should be used, and the manure should be removed more frequently than once a day, and, in any case, not immediately before milking. The walls and ceiling should be swept often enough to prevent the accumulation of dust. Once a year, at least, it is wise to clean the whole stable with extreme care and then go over the whole with a generous coat of whitewash. At such a time, the stable should be thoroughly disinfected, if there have been any contagious diseases in the stable. The surroundings outside of the stable should be kept in a clean condition, so as not to interfere with the supply of pure air.

(2.) The Body of the Cow.—Too much pains cannot be taken to keep the cows clean. In addition to regular currying and brushing all over, the udder and adjacent portions of the body should be carefully brushed before milking and also wiped with a damp, clean cloth. The udder should also be wiped after milking.

(3.) The Milker should wash his hands carefully before milking and have them perfectly dry while milking. It is also desirable to have a special coat or jacket for milking, made of some material that will not catch or hold dust easily.

(4.) The Dairy Utensils.—All utensils that come in contact with the milk, such as milk-pails, milk-cans, aerators, etc., should be made of metal, preferably of pressed tin, with smooth, well-flushed joints and perfect seams. They should be kept entirely free from rust. Such vessels should never be allowed to dry when dirty, as dried particles of milk are particularly difficult to remove. In cleaning dairy utensils, rinse them first with lukewarm water and then wash them thoroughly in hot water, using soap or washing soda. Then rinse them with hot water and complete the cleansing, if possible, by exposing to a jet of live steam for three to five minutes.

When practicable, expose them finally to direct sunlight for a few hours. Strainers should be washed immediately after using, cleaning first in tepid water, following with hot water and soap and finally with hot water and steaming or boiling.

(5.) Time of Feeding.—Foods having marked odors should be fed only after milking and then at once, and none should be left in the stable. Dry fodders, which furnish dust, should likewise be fed after milking.

(6.) Diseased Milk.—The milk of diseased animals should not be used nor that of animals fresh in milk before the ninth milking.

(7.) Contagious Diseases.—No person suffering from, or recovering from, a contagious disease, nor any person that has anything to do in caring for such a person should be allowed to have any contact with the dairy.

(8.) Removal from Stable and Subsequent Treatment.—As soon as each cow is milked, the milk should be removed from the stable to some room free from all bad odors and with cleanly surroundings. The milk should be at once strained through a brass-wire strainer, having not less than fifty meshes to the inch, and also through three or four thicknesses of cheese-cloth. Still more effective results in straining can be secured by the use of absorbent cotton, though its expense makes its use impracticable under ordinary conditions. After straining, cool to 50 degrees F., or below.

By observing precautions like these, it is easily possible to reduce the number of bacteria in the milk to such an extent that the milk will keep eighteen to twenty-four hours longer than ordinary milk. Precautions like the foregoing for keeping bacteria out of milk are practicable, where one owns a herd of cows and has all conditions under personal control; but it is another matter when it comes to making some one else observe them. So, when milk is not under one's control, the next best thing is to prevent the growth of the bacteria already in the milk, and this may be done by use of low temperature in keeping the milk or by heating the milk first and then cooling. One method prevents or delays the growth of bacteria without destroying the germs themselves, while the other destroys most of the bacteria.

14. Preventing or Delaying Growth of Bacteria in Milk.

Whether precautions have been taken or not to keep large numbers of bacteria from getting into milk, it is necessary, as soon as milk is drawn, to cool it quickly, and the lower the temperature, the better. At temperatures below 50 degrees F., the rapidity of growth of the bacteria is greatly lessened. In connection with the cooling

of milk, it is well, at the same time, to aerate it, in order to remove the natural "animal" odor or any other odor that may have been absorbed by the milk after milking. There are several special forms of aerators in the market (see Figs. 1 and 2) that serve for both cool-

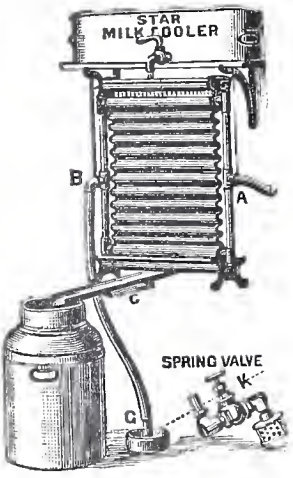

Fig. 1.

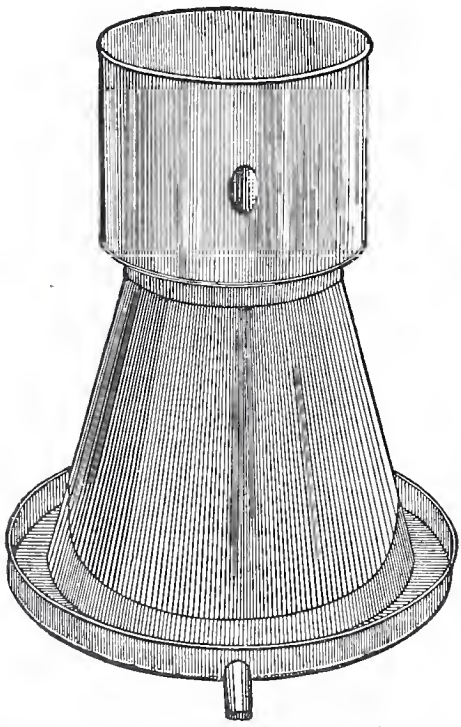

Fig. 2. Champion cooler and aerator.

ing and aerating the milk at the same time. The main points to be considered in selecting an aerator or a combined aerator and cooler, are simplicity of construction, ease of management, effectiveness in cooling and aerating and convenience in keeping clean. Aeration must always take place in an atmosphere as free as possible from bacteria; otherwise the process will only increase the number. The use of low temperatures in keeping milk gives the best results only with the milk that is most free from bacteria.

15. Destroying Bacteria in Milk.

In the case of milk that contains large numbers of germs, the most effective way to keep the milk from souring and from the development of other forms of fermentation is to destroy the bacteria. This may be best accomplished by heating the milk. While it is possible to add to milk chemicals that will destroy bacteria without affecting the composition or taste of the milk, the use of preservatives is very generally condemned for this purpose on the ground that they may injuriously affect the health of people using milk

thus treated. The use of preservatives, such as salicylic acid, boracic acid, formalin, etc., for the purpose of keeping milk is not to be recommended. In employing heat to kill bacteria, two general methods have been used, known as pasteurizing and sterilizing.

(1.) Pasteurizing Milk.—In pasteurizing milk for market, it is heated to 140 degrees F., and held at that temperature for twenty or thirty minutes. Formerly, higher temperatures were used, but it was found that milk, heated above 156 degrees F. acquired a "cooked" taste and that the cream did not readily rise. While the lower temperature does not destroy all germs, it destroys most of them and greatly improves the keeping power of milk. To secure best results in pasteurizing, it is desirable to use milk as fresh as possible. Milk containing 0.2 per cent of lactic acid does not give good results. The fewer bacteria milk contains before pasteurizing, the better will be the results of pasteurization. It is also very essential in pasteurizing that the heated milk should be cooled down at once to 50 degrees F., or lower. It should also be stored in germ-free bottles or other vessels and kept cold until it is delivered to the customers. When used by children, pasteurized milk should be consumed within twenty-four hours after treatment. If pasteurization is properly carried out, the milk should remain sweet, even at ordinary temperatures, one and one-half to two days longer than ordinary milk not so treated.

There are on the market several forms of machines for pasteurizing milk. The best machine should possess the following qualifications: (a) Compact form, (b) ease of keeping clean, (c) complete control of temperature, (d) ability to heat milk quickly, completely and uniformly, (e) freedom from liability of additional germs getting into the milk during the operation of pasteurizing.

The pasteurization of milk has the following advantages: (a) It increases the keeping quality of milk. (b) It destroys disease-germs, especially those of tuberculosis. (c) The taste and digestibility of milk are not changed. (d) The process is practicable on a large or small scale.

(2.) Sterilizing Milk.—In order to render milk absolutely free from all bacteria and their spores, it is necessary to heat milk above 212 degrees F. for an hour on each of three successive days, thus giving all spores a chance to develop into active forms, which are then more readily killed. Simple boiling is effective in destroying practically all living disease-germs. Sterilized milk is objectionable for several reasons: (a) It has the characteristic taste of "cooked" milk, which is unpleasant to most people. If people had only sterilized milk to drink, very much less would be used. (b) Sterilized milk appears to be less digestible, especially in the case of children and invalids.

CHAPTER IV.

CREAM.

16. Composition of Cream.

Cream is the fluid product, rich in milk-fat, obtained by removing milk-fat from milk in any manner, along with some portions of other milk constituents. Cream contains the same constituents as milk, but in very different relative proportions. Cream contains much more fat than does milk, but less of the other constituents. Cream varies greatly in its fat content, ranging all the way up from 10 per cent. or less. Market cream often contains less than 15 per cent. of fat, but good cream for domestic use, at the prices commonly charged, should contain 20 to 25 per cent. of fat. The amount of fat in cream depends upon a variety of conditions, but chiefly the method employed in removing the cream from the milk. For illustration, we give the composition of several different samples of cream in the following table:

Per cent. of water.	Per cent. of fat.	Per cent. of casein and albumin.	Per cent. of sugar.	Per cent. of ash.
76.60	15.0	3.1	4.5	0.6
66.30	25.0	3.2	4.8	0.7
62.40	31.5	2.6	3.0	0.5
39.40	56.0	1.6	2.3	0.4

In the separation of cream, the individual fat-globules are not in any way affected; they are simply crowded together in less space than in milk.

17. Separation of Cream.

The fat-globules in milk are relatively lighter than the milk-serum, in which they float free in the form of an emulsion. When milk is permitted to remain quiet in a vessel, the fat tends to rise and accumulate at the surface of the liquid, owing to its lighter specific gravity, relative to milk-serum. In thus passing up through the milk, the fat-globules mechanically carry with them some of the milk-serum. Until recent years, cream was all produced by allowing the fat-globules to separate by gravity, but there have come into gradual use machines that are used to separate cream from milk

by means of centrifugal force. Hence, we have in use two general methods of cream separation, (1) the gravity system, and (2) the centrifugal or separator system.

18. Gravity Method of Cream Separation.

The gravity method of cream separation has been used in two different forms, one known as the "shallow-pan" system and the other as the "deep-setting" system.

(1.) Cream Raising by Shallow-Pan System.—This is the oldest method employed in separating cream from milk. It is still employed in many small dairies. To obtain the best results with this method, the milk should be placed in the pans at once after milking and should be cooled to 60 degrees F. within a reasonably short time, and should then remain quiet at about that temperature for thirty-six hours or more. The depth of milk in the pan may be from two to four inches. When cold running water can be used to surround the pans ,the depth may be from four to six inches. Ordinarily a cool, clean cellar, well ventilated, furnishes good conditions. Any place where the milk can be exposed to bad odors or to dust should be avoided. There are some serious objections to this method of creaming, among which may be mentioned (a) exposure of a large surface of milk to air for a long time, thus giving unusual opportunity for bacteria to get into the milk; (b) a temperature permitting the rapid increase of bacteria by growth; (c) incomplete separation of fat-globules from the milk serum; (d) wasteful loss of cream in skimming; (e) drying out of cream, making it liable to go into butter in dried chunks and injure the texture. (f) The amount of acid in the cream is apt to become too great, thus injuring the flavor of the butter. It has been found that skim-milk obtained by the shallow-pan system of creaming seldom contains less than 0.5 per cent. of fat, while the average of actual practice is much higher, amounting to about one-fifth of the entire fat present in the milk.

(2.) Cream Raising by Deep-Setting System.—This method has been in use between thirty and forty years, probably reaching its most extensive use ten years ago. It was found that by using long pails or cans, not more than a foot in diameter, and placing these, filled with fresh milk, in a tank of water kept at 40 degrees F., the cream would separate more completely and in much less time than it would when raised in shallow pans, twelve to twenty-four hours being sufficient for the separation. This system is capable of reducing the loss of fat in skim-milk to 0.2 per cent., when the most

favorable conditions are present. This method also has the advantage of greatly diminishing the amount of exposure to air, thus preventing additional bacteria getting into the milk from the air during the creaming process. Owing to the low temperature employed, the growth of bacteria in the milk is greatly retarded. To use this system satisfactorily, ice is necessary. The cream raised by the deep-setting method is not very rich, usually containing between 15 and 20 per cent. of fat.

In the gravity method of cream-raising, the rapidity and completeness of separation of cream are dependent upon several different factors, among which may be mentioned (a) the size of the fat-globules, (b) the amount of solids in the milk-serum (the solids-not-fat), and (c) the relative proportions of the different solids in the serum. The larger fat-globules separate from the milk more quickly than the smaller ones do. The size of fat-globules varies with individual cows, with breeds, with advance of the period of lactation, and with other conditions. The fat-globules in the milk of cows fresh in milk are larger than later in the lactation period, decreasing in size as the cow is farther from the beginning of her period of lactation. The solids-not-fat in milk, that is, the casein, albumin, sugar and mineral salts cause milk to have the property of what is called *viscosity;* by this is meant the power of adhering to other solid things. The presence of these solids in milk gives milk the power of adhering to fat-globules, thus offering resistance to their tendency to rise or move in any direction. Now, the greater the amount of these solids-not-fat in milk, the more opposition do the fat-globules have to overcome in rising, and the more slowly and incompletely does such milk cream. It is well known that, as a cow gets farther along in her lactation period, the casein and albumin increase more rapidly than do other constituents and they greatly increase this viscosity of the milk. Hence, with advance of lactation, we have two different factors increasing all the time in the milk that interfere with the raising of the cream, viz: decrease in size of fat-globules and increase of viscosity. This explains why the gravity method of creaming gives less satisfactory results when a cow is far along in milk than when she is fresh. To overcome these adverse conditions, various expedients have been tried, the most common being dilution of the milk by water, both warm and cold. The advantages secured in this way are doubtful and the disadvantages accompanying such a practice are considerable.

19. Separation of Cream by Centrifugal Force.

It is not our purpose to discuss the details of the mechanism of centrifugal machines or to describe the different varieties in the market. We intend simply to make a few statements in regard to

the general principles applying to their use and the results secured. There are on the market many different forms of these machines, and between many of them there is very little choice in respect to their relative efficiency. If any one, not well informed about separators, plans to purchase one, it is suggested that it would be desirable to correspond with the Experiment Station at State College and obtain authoritative advice in regard to the qualities of different machines rather than to rely wholly upon the persuasive statements of agents who are ambitious to sell machines.

All centrifugals designed for separating cream from milk are based upon the same general principle. The milk enters a rapidly whirling bowl and at once partakes of the centrifugal motion, being thrown by the centrifugal force to the extreme wall of the bowl. As the milk continues to flow in, the bowl fills from the outside toward the center. The centrifugal force acts more strongly upon the heavier portion of the milk, that is, the milk serum or all the milk except the fat. Hence, the milk-serum is forced to the outside wall of the bowl, while the lighter portion of the milk, the fat with some adhering serum, is forced to the center. Tubes connect with the skim-milk layer at the outer wall and with the cream layer at the center of the bowl to carry away these products as they accumulate. The outer walls of the separator bowl gradually become covered with some of the solid, heavier constituents of the milk, including solid dirt present in the milk, forming what is known as "separator slime," the composition of which we will notice later.

(1.) Conditions Affecting Creaming Efficiency of Separators.—The efficiency with which separators remove cream from milk depends upon several different conditions, some of which we will briefly consider.

(a.) The intensity of centrifugal force affects the efficiency of a separator. This increases as the diameter of the bowl increases and also when the bowl whirls rapidly. So, the larger the bowl, and the greater the speed of the bowl, the greater is the contrifugal force and also the creaming efficiency.

(b.) The rate at which the milk flows into the separator bowl affects the creaming efficiency. The more slowly the milk flows in, the longer it is under the action of the centrifugal force and the more completely is the fat removed from the milk.

(c.) The temperature of the milk when run through the separator affects the creaming efficiency. The warmer the milk, the more easily the fat separates. The temperature commonly employed is from 76 to 98 degrees F. In producing cream for butter-making, the milk should be separated at as low a temperature as possible without diminishing the creaming efficiency, because heating

the fat-globules above a moderate temperature tends to produce butter of soft texture.

(2.) Regulating Richness of Cream.—The richness of cream produced by a separator is regulated by the rate at which the milk flows into the bowl and by the rapidity with which the bowl revolves. The more rapid the inflow of milk or the slower the speed of the bowl, the larger the quantity of cream and the poorer in fat. Most machines are provided with special arrangements for regulating the richness of cream without changing the rate of inflow or rapidity of motion.

(3.) Creaming Efficiency of Separators.—A good centrifugal separator should not leave more than one-tenth of one per cent. (0.1 per cent.) of fat in the skim-milk, when it is run under proper conditions.

(4.) Promptness in Separating Milk.—Milk should be separated as soon as practicable after milking, and the cream should be cooled down to 50 degrees F., or below.

(5.) Advantages of Creaming by Centrifugal Machines.—Among the advantages that may be mentioned in favor of employing centrifugal machines in separating cream from milk are the following:

(a.) There is a great saving of fat. Gravity systems of creaming leave, on an average, 0.5 per cent. of fat or more in the skim-milk, while good separators properly handled should not leave more than 0.1 per cent. In a large number of comparative experiments made by the writer, where milk from different breeds of cows was creamed both by the deep-setting gravity system and by centrifugal machine, it was found that the separator effected a saving of fat amounting to twenty-four to sixty-five pounds a year for each cow. In the form of butter, at twenty cents a pound, this saving for each cow would be equivalent to $5.00 to $15.00 a year.

(b.) In the case of cream separation by the gravity system, the composition of the cream is not under satisfactory control, and will vary, even under the most uniform conditions of creaming, 5 per cent. of fat or more. One can never be sure in advance of what the fat content of gravity-raised cream will be. In the case of cream separated by a centrifugal machine, one can so regulate the conditions as to produce cream with just the desired amount of fat in it. It is thus easy to produce a product that is uniform in composition, since the conditions are under easy control. In the case of producing cream for sale as such, it is very important that the product shall be uniform from day to day.

(c.) Separator cream is more free from dirt and bacteria and will keep longer than will gravity cream. Most of the dirt in milk in the form of solid particles is completely removed by the centrifugal separator, as the appearance of the separator slime abundantly testifies.

(d.) The skim-milk produced by separator creaming is sweeter and more free from bacteria and dirt than that produced by gravity creaming. Separator skim-milk is, therefore, better for feeding purposes.

20. Artificial Thickening of Pasteurized Cream.

When cream is prepared to sell for immediate consumption as cream, its keeping power can be very greatly increased by pasteurizing at 140 degree F., without affecting its taste. However, some of the physical properties of the cream are so changed by pasteurizing that it appears thinner after pasteurization, though containing the same amount of fat. Pasteurized cream, therefore, gives the impression of being poorer in fat, and is much more difficult to make whipped cream from. Babcock and Russell have devised a simple, effective and absolutely harmless method of restoring the proper consistency or body, to pasteurized cream. This consists in the addition of a small amount of "viscogen," which is an entirely harmless compound made from lime-water and ordinary granulated sugar. Viscogen is prepared as follows: Take two and one-half parts, by weight, of granulated sugar and dissolve in five parts of water. To this add some lime-water prepared thus: To one part of quick-lime add three parts of water, stir thoroughly until the lime is completely slaked, strain and this liquid, which is simply lime-water, is added to the solution of cane sugar. The mixture of lime-water and cane sugar is shaken or stirred at intervals for two or three hours, after which it is allowed to stand until settled. Then the cleared liquid is poured off and stored in tightly-stoppered bottles ready for use. Of this liquid, thus prepared, add one ounce to three gallons of cream and stir thoroughly. Sometimes a little more is needed. As many States have stringent laws against the addition of any kind of foreign substance to milk or cream, cream to which viscogen has been added should not be sold as simple cream, but as a special preparation of cream. Moreover, customers should be given the choice of buying cream with or without viscogen, as some people have a prejudice against additions of any kind to their dairy food products. However, the use of viscogen is just as harmless to health as the use of so much common salt.

21. Profits Derived from Selling Cream.

There is no form under which milk can be sold at so great a net profit as in the form of cream. The labor involved and the cost of preparation are much less than in the case of making butter or cheese. The skim-milk may all be kept on the farm, while in the

case of milk-selling and cheese-making there is none. At the market rates commonly prevailing for dairy products, the price received for cream is higher, relative to its cost of production, than is the price of an equivalent amount of milk, butter or cheese. An investigation made by the writer some years ago indicated that the net profit from selling cream is nearly three times that from butter, nearly four times that from selling milk and about seven times that from selling cheese. While the demand for cream is limited, it has been steadily increasing. Any dairyman, so circumstanced that he can dispose of his milk in the form of cream directly to customers, should make an effort to develop this form of trade.

22. Composition of Skim-Milk.

Skim-milk is the product, containing water and milk-solids that remains when any portion of fat normally present is removed from milk in the form of cream by any means whatever. It is essentially milk-serum with some milk-fat in it. Skim-milk varies in composition according to the composition of the milk before skimming, and according to the method of creaming.

(1.) Difference in Composition of Gravity and Separator Skim-Milk. —Separator skim-milk differs in composition from gravity skim-milk chiefly in the amount of fat present. The following figures serve as a good illustration to show the difference in such composition:

	Gravity skim-milk — Per cent.	Separator skim-milk—Per cent.
Water,	90.00	90.30
Fat,	0.50	0.10
Casein and albumin,	3.50	3.55
Milk-sugar,	5.20	5.25
Ash,	0.80	0.80

(2.) Difference in Composition of Skim-Milk from Different Kinds of Milk.—We will illustrate next the difference in composition of skim-milk due to difference in composition of the original milk before skimming. For this purpose, we will consider only the total solids of the milk, as this will sufficiently illustrate the point we

wish to bring out. We will assume that each of the milks represented is creamed by a separator and that all of the fat but one-tenth of one per cent. is removed:

	Per cent. of total solids in milk.	Per cent. of fat in milk.	Per cent. of total solids in skim-milk.
Milk No. 1,	11.80	3.30	8.90
Milk No. 2,	12.65	3.60	9.50
Milk No. 3,	14.50	4.60	10.50

There has been common an idea that the skim-milk from milk rich in fat is of inferior quality to skim-milk from milk less rich in fat. The figures above show that this idea is erroneous. The richer a milk is in fat, the richer it is in solids-not-fat, that is, skim-milk solids. A hundred pounds of skim-milk from rich milk contains more casein, albumin and milk-sugar, as a rule, than will a hundred pounds of skim-milk less rich in fat, provided, of course, that the method of removing fat is the same.

Some writers have made a distinction in name between skim-milk obtained by the gravity process of creaming and that obtained by the separator process, calling only the former skim-milk, and applying the term "separated milk" to separated skim-milk. The distinction is without justification and quite uncalled for, since skim-milk is the product left after removing fat from milk, without reference to the method employed in removing the fat.

23. Valuable Uses of Skim-Milk.

Skim-milk has come to have a variety of uses, giving it a definite value. To the dairy farmer, the most valuable use to which he can put skim-milk is, undoubtedly, as food for animals. The composition of skim-milk, as given above, shows considerable quantities of casein and albumin and milk sugar, all of which are important food constituents in forms readily digestible. Skim-milk should preferably be fed sweet, as some of the sugar is lost by fermentation, and marked acidity does not always agree with the digestion of young animals. Skim-milk may be fed to advantage in connection with other foods to all kinds of farm animals.

Skim-milk is also a valuable food for human beings, both in the form of a beverage and in cooking. It should be used much more extensively than it is. Unfortunately, dishonest milk dealers have tried fraudulently to sell skim-milk as whole milk, so that the sale of skim-milk has to be attended with annoying restrictions.

Skim-milk is also used in considerable quantities in the manufacture of cottage-cheese.

The casein of skim-milk is used for a variety of purposes, among which may be mentioned, its use as sizing or dressing in the manufacture of paper as a substitute for celluloid, and as a constituent of plastics for a great variety of purposes.

24. Composition of Separator-Slime.

The separator-slime, which collects on the walls inside the separator-bowl, consists largely of milk-casein, in which are collected all kinds of solid impurities contained in the milk, such as dust, fine particles of hay, ground grain, dung, cow hairs, etc. It is heavily loaded with bacteria. The chemical composition of separator-slime is about as follows:

	Per cent.
Water,	67.0
Fat,	1.0
Casein,	26.0
Milk-sugar,	2.0
Ash,	4.0

On an average, 2,500 pounds of milk produce one pound of separator-slime. The amount increases with the amount of dirt present in the milk.

CHAPTER V.

BUTTER-MAKING.

In taking up the subject of butter-making, we assume that we have the cream to start with. The question is sometimes asked why it is necessary to remove cream from milk for butter-making, why not churn the milk itself? Experiments in churning milk have never succeeded in removing the fat from the milk at all completely and the method results in large losses of fat with consequent decrease in yield of butter.

In the case of cream that has been separated by a centrifugal machine, it is important to cool the cream to 50 degrees F. or below, without delay, and to hold it at this temperature for six or eight hours. This cooling appears to be important, in order to obtain butter with sufficiently firm texture. In general, it may be said that we shall be most successful in making butter having the best texture, when the milk and cream are subjected to the fewest changes of temperature and when the changes of temperature that are needed are made in the most gradual, uniform manner.

After having the cream in the condition indicated above, we perform the following different operations in making butter:

(1.) Ripening the cream.
(2.) Churning.
(3.) Washing and working.
(4.) Salting.
(5.) Packing.

After considering the composition of butter, we will take up, in their proper order, the different operations required for making butter.

25. Composition of Butter.

The composition of butter varies considerably, according to the methods and conditions of manufacture. The principal variations are in the fat and water. The following tabulated statement serves to give an idea of the usual limits of variation in composition of American butters, but there are extreme cases lying outside the limits here given:

Per Cent. in Butter.	Low.	High.	Average.
Water,	10.0	15.0	13.0
Fat,	80.0	85.0	83.5
Casein,	0.5	2.0	1.0
Ash (salt),	1.0	4.0	2.5

Good commercial butter should contain over 80 per cent. of fat, and not more than 15 per cent. of water or 3 per cent. of casein.

26. Ripening Cream for Butter-Making.

The ripening of cream is essentially the process of developing enormous numbers of certain kinds of bacteria in cream, the most prominent ones in point of numbers and visible activity being lactic

acid bacteria. When butter is made in the old way, the cream is allowed to stand until it ripens spontaneously, no attempt being made to control the process. As the result of the fermentations that occur in the ripening process, many complex changes take place in cream, the details of which are not fully understood. The most obvious results brought about by cream-ripening may be included under three general heads; (1) The formation of lactic acid, (2) the development of products that have charactertistic odors, and (3) the formation of substances that yield a characteristic taste on the tongue. To what extent these effects are produced by special organisms, we have little detailed knowledge, aside from the work of lactic acid bacteria in producing lactic acid. The real sources of the flavors of ripened cream we do not know specifically, nor do we know what these specific compounds are that give rise to the flavors. The amount of lactic acid formed is used as a measure of the extent or degree of cream-ripening, but other forms of fermentation are known to be present at the same time, at least during the early portion of the ripening process. Butter may be made from cream that has not been ripened at all, that is, from sweet cream, or it may be made with the help of artificial acid added to cream, but in neither case do we make a product that is in flavor like butter made from ripened cream.

27. How Lactic Acid is Produced in Cream Ripening.

In order to have the lactic acid fermentation of cream ripening, lactic acid bacteria must be present in the cream and the cream must be kept at a temperature favorable to their growth. We may leave the cream to receive the bacteria by chance, or we may introduce them into the cream purposely. In the old-style method of butter-making, the former method is employed. We have already seen (section 12, p. 25), that milk nearly always contains lactic acid bacteria. During the operation of creaming, these bacteria usually develop to such an extent that, when the cream is exposed to higher temperatures, fermentation proceeds rapidly. However, under such circumstances, the rate of fermentation is not uniform in different lots of cream; at one time more lactic acid is formed, and at another less, during a given time, because the number of bacteria will inevitably vary greatly when their introduction is left to chance.

The formation of lactic acid can be controlled in respect to time and quantity, when we introduce the lactic acid bacteria purposely in sufficient quantities. Material, containing large numbers of lactic acid organisms, which is used to add to milk or cream for the purpose of causing lactic acid fermentation, is known as a "starter." There are two varieties or sources of starters, (1) natural, and (2) pure cultures.

(1.) Natural Starters.—Among the materials used as natural starters in butter-making are buttermilk and cream from previous operations of butter-making, and whole milk or skim-milk soured under special conditions. While there are different ways of preparing natural home-made starters, the following method may be suggested as one that will give good results, if properly carried out: Milk is taken from a cow in perfect health, not too far along in lactation, and kept under proper conditions of cleanliness. The udder and under parts of the cow's body are brushed and then wiped with a damp cloth, after which the cow is milked into a carefully cleaned vessel, the first few streams of milk from the udder being thrown away. The milk thus drawn is at once covered, taken to the dairy and run through the separator. This skim-milk, put into a carefully cleaned receptacle, is carefully covered, brought to a temperature of 90 degrees F., after which it is placed where it will keep at a temperature of 65 degrees F. to 70 degrees F. In twenty to twenty-four hours, the skim-milk will be found properly ripened or just moderately thickened. In using this prepared starter for ripening cream, the upper portion to the depth of one or two inches is removed and thrown away, the rest is strained through a fine strainer or hair seive into the cream, which should be at 70 degrees F., in the proportion of two pounds of starter for 100 pounds of cream. The starter should be thoroughly stirred into the cream, the cream vat covered and kept at a temperature of 65 degrees F. to 70 degrees F. Usually twenty-four hours will develop the proper amount of acid for churning. When the cream is properly ripened, it should just form a soft curd, not a hard curd. In case of over-ripening, when the curd becomes too hard, there is danger that some of this coagulated casein will get into the butter and injure its quality and appearance. Some of this prepared starter, described above, may be used in preparing a starter for the day following, putting a little into skim-milk that has been heated to 180 degrees F. for thirty minutes and then cooled down to 70 degrees F., and the starter may thus be propagated from day to day; but this method of propagating must not be continued too long, as the starter gradually becomes inoculated with undesirable forms of bacteria and sooner or later is unfit for use. These natural starters may be used in either pasteurized or unpasteurized cream.

(2.) Pure-Culture Starters are special preparations consisting of certain specific selected organisms, known to be adapted to the work of cream ripening. There are on the market several different preparations for ripening cream, consisting of special cultures. Such commercial artificial ferments give the best results, when used in pasteurized cream The chief advantage found by experience to

come from the use of these pure culture starters is uniformity in character of the butter produced and better keeping quality. Full directions for methods of use always accompany these special starters and we do not need to consider them here.

28. Amount of Acid Needed for Cream Ripening.

The ripening of cream was, for a long time, the most difficult step of butter-making to control, and the specially difficult point in this operation was to determine the amount of acid that should be present before churning. The appearance, odor and taste of the cream are guides, to some extent, as to the amount of acid formed, but they are far from reliable for accurate, uniform work. It is very important that the same amount of acid shall be developed from day to day in order to secure butter of uniform quality. When cream is ripened so as to show a test of five-tenths to six-tenths of one per cent. of lactic acid, it produces a higher flavored butter than that produced by cream ripened to four-tenths of one per cent. of acid. When cream contains more than sixty-five hundredths of one per cent. of acid, the flavor of the butter is too strong. Moreover, in such cases, the particles of coagulated casein become very hard and form white specks in the butter. Such butter acquires bad flavors quickly. The whey should never separate from the curd in cream ripening. We now have an inexpensive, simple method for determining the amount of acid in cream, and, while the method is not strictly accurate, it is sufficiently close for all practical purposes in cream ripening. For careful work in butter-making, this method of determining the amount of acid in cream should always be used. The method is fully described in section 90, p. 111, Chapter XI.

29. Effects Produced by Cream Ripening.

The effects of cream ripening are seen in several different ways, among which we will notice the more important.

(1.) Improved Flavor of Butter.—In order to secure butter with the kind of flavor required by the average consumer, it appears to be necessary to ripen cream. This is probably the most important and far-reaching effect of ripening cream. The importance of flavor in butter is easily obvious, when we consider that flavor more than any other factor determines the market price of butter. Poor cream ripening means poor flavor and low price for butter.

(2.) Ease of Churning.—It has been found true, especially in cream raised by the gravity system, that cream churns more readily when ripened. This is probably due to the influence of acid upon casein.

(3.) Increased Yield of Butter.—In ripened cream, churning appears to remove the fat more completely from the cream, especially in the case of gravity-raised cream, and, consequently, the yield of butter is greater.

(4.) Better Keeping Quality of Butter.—It is quite generally believed that the keeping quality of butter is better when made from properly ripened cream than from cream improperly ripened.

(5.) Greater Uniformity in Quality of Butter.—It is undoubtedly true that only by the use of properly ripened cream is it possible to produce butter that is uniform in quality from day to day. This is a matter of the first importance to butter makers, because the same customers want the same kind of butter, when they once get the kind that suits them.

30. Mixing Cream of Different Ages.

It often happens that when the amount of cream produced in a day is small, that the cream each day is set aside and additions of new cream made from day to day, until enough has been accumulated for churning. There results a mixture of cream varying in degrees of ripeness. The different portions vary in the length of time in which they will churn, one portion requiring less churning than another. The result is that churning is stopped before all the fat has been removed from the cream and much fat is lost in the buttermilk. The flavor of butter made from such cream can hardly be as uniform as that made from cream uniformly ripened. If different creams, varying in degree of ripeness, are to be churned together, it is essential that they should be mixed together, at least twelve hours before churning; then the degree of acidity will be uniform throughout the entire mass of cream.

31. Pasteurizing Cream for Butter-Making.

In pasteurizing cream for butter-making, less care is required than when cream is pasteurized for direct consumption. The cooked taste occurring in cream when heated above 156 degrees F. is absent from butter made from such cream, even when cream has been heated at high as 185 degrees F. High heating of cream, however, acts injuriously upon the texture of the butter. In using pasteurized cream for butter-making, the heated cream should be quickly and completely cooled after pasteurization, and the ripened cream should be chilled to 48 degrees F. for about two hours before churning. Treatment in this manner overcomes the tendency of any injury occurring to the grain or texture of the butter.

32. Richness of Cream for Butter-Making.

How rich in fat should cream be made for butter-making? By the gravity method of creaming, we obtain cream containing 15 to 20 per cent. of fat, and by the separator we produce cream of any fat content desired. Good results in every respect may be obtained by the use of cream varying greatly in fat content. The tendency has been to use rather rich cream containing 35 to 40 per cent. of fat, in which case a lower temperature is used in churning, usually with loss of less fat in buttermilk. In order to ripen rich cream in the same length of time as poorer cream, somewhat more starter needs to be used, as the richer cream ripens more slowly than poorer cream under the same conditions.

33. Conditions Affecting Churning.

Churning is the term applied to the process by which the fat-globules of milk or cream are made to unite into visible aggregations, and to separate from the milk-serum or buttermilk. This massing together of fat-golbules is usually produced by the vigorous agitation of cream in vessels especially constructed for the purpose, called churns. When milk or cream is agitated at a temperature somewhat below 85 degrees F., the average melting-point of milk-fat, the fat-globules gradually attach themselves together, each of the small masses first formed continuing to increase in size by uniting with others, until finally the whole of the fat, thus separated, can be collected in one mass. The readiness with which fat-globules separate from cream in churning is influenced by several conditions, among which we may mention, as the most important, (1) the composition and size of the fat-globules, (2) the composition of the milk-serum, (3) the degree of ripeness of the cream, (4) the temperature used in churning, and (5) the kind of agitation or churn.

(1.) Composition and Size of Fat-Globules.—The readiness of fat-globules to separate from milk-serum and unite in visible masses during the process of churning, is influenced by the composition and size of the fat-globules. As pointed out in section 3, p. 13, milk-fat varies in its composition, and this variation in composition affects the hardness or softness of the fat. This quality is influenced by the character of the cow's food. Thus, succulent feeds and feeds rich in starch and sugar make the fat softer. Cottonseed-meal makes the fat harder. Now, it is known that the fat-globules unite more easily in churning when they are composed of softer fat, and less readily when they have larger proportions of hard fat.

In respect to the influence of the size of fat-globules upon ease of churning, the larger the fat-globules the more easily and quickly

they unite. Owing to their size, the larger ones come into contact more quickly and more often than do the smaller ones.

(2.) Composition of Milk-Serum.—The albumin, casein and milk-sugar contained in milk or cream tend to keep the fat-globules from coming together easily. The larger the amounts of these constituents, the less readily will the fat-globules come together. This is one of the reasons why churning is often so slow and difficult in the case of cream from the milk of cows far along in lactation, since at that time milk contains larger proportions of these constituents than earlier in lactation.

(3.) Degree of Ripeness of Cream.—The fat-globules of ripened cream churn more readily and completely than those of sweet cream under like conditions, especially in the case of cream raised by gravity. The lactic acid coagulates the casein and thus greatly decreases the strong influence it has in its usual condition to keep the fat-globules from coming into contact with one another.

(4.) Temperature Used in Churning.—The condition that exercises most influence upon the ease with which the fat-globules unite in churning is the temperature of the cream. This determines, more than any other factor connected with churning, the hardness or softness of the fat-globules. When the temperature is too low, the fat-globules are so hard that they do not stick together when they come into contact, and, consequently, no butter results. When the temperature is too high, the agitation of the fat-globules in churning tends to break them up into smaller globules rather than to unite them into larger masses, thus forming a more complete emulsion, more difficult to churn than the original cream. Fat-globules may be made to unite at temperatures as low as 46 degrees F., and as high as 80 degrees F. Thus, the range of possible churning temperatures is very considerable, but the quality of butter produced at different temperatures is very different, particularly in texture. The butter is in the most satisfactory condition at the end of churning, when the temperature of the cream during churning has been such that the fat-globules have united readily into firm, solid granules of butter, with a minimum content of buttermilk. No particular temperature can be prescribed for churning, as other conditions enter in to modify the temperature of churning, such as (a) the individuality of cows, (b) the stage of the lactation period, (c) the character of the food eaten by the cows, (d) the season of the year, (e) the thickness of the cream, and (f) the degree of its ripeness. The conditions mentioned that are immediately connected with the cow, influence the composition of the milk-fat, making it harder or softer, as stated above. The harder the milk-fat, the higher the temperature at which churning should be done, and the softer the milk-fat, the

lower the proper churning temperature. In the case of cream from the milk of cows far along in lactation, or of cows fed exclusively on dry feed or with considerable cottonseed meal in the ration, the churning temperature usually needs to be higher. In the case of cream from the milk of cows in the earlier stages of lactation, or of cows fed on succulent foods or foods rich in starch or sugar, the churning temperature should be lower. Generally speaking, a lower churning temperature should be used in summer and a higher one in winter. The richer cream is in fat, the lower the temperature that can be used successfully in churning, and the poorer the cream is in fat, the higher should be the temperature of churning, all temperatures, of course, being within the limits required for making butter of good quality. For example, cream containing 15 per cent. of fat may be churned at 58 degrees F. to 62 degrees F.; cream containing 40 per cent. of fat may be churned at 50 degrees F. Lower temperatures remove the fat most completely. Ripened cream can be satisfactorily churned through a greater range of temperature than sweet cream can, especially in the case of cream raised by gravity. From the foregoing statements, it can readily be seen that no fixed temperature can be given as the correct one at which cream in general should be churned.

(5.) Kind of Churn.—Different churns are made so as to give each a different kind of motion to the cream in churning. Thus, we have (a) churns with a beating action, (b) swinging, cradle and rocking churns, (c) horizontal churns with dash, (d) vertical churns with dash, end (e) churns with a variety of special contrivances for stirring the cream. On the whole, experience appears to show that the best churns are simple barrel or box churns, entirely hollow, without special paddles or stirring apparatus inside. In such churns, the agitation of the cream is caused by the striking of the particles of cream upon the sides of the revolving churn rather than by a stirring motion. When paddles or other means of stirring are used in churning, it is believed that the texture of the butter is liable to be injured. The speed of churning should be such that the motion of the cream will stop just short of taking on the centrifugal motion of the churn. The object to be kept in view is that the particles of cream shall move about against one another most frequently and thus give the fat-globules the greatest chance to come into contact one with another.

34. When to Stop Churning.

Butter is said to "begin to come," or to "break" when the fat-globules have formed masses sufficiently large to be readily seen in the cream. From this point, the process of churning is soon

completed. In finishing the operation of churning, two points should be aimed at, (1) completeness of churning and (2) retention of smallest practicable amount of buttermilk in butter granules.

(1.) Completeness of Churning.—By completeness of churning we mean the extent to which the fat has been gathered from the milk-serum into butter. This is shown by the amount of fat left in the buttermilk, and is governed by several conditions, which have already been mentioned. Thus, the loss of fat in buttermilk is greater in mixed creams of varying degrees of ripeness than it is in uniformly ripened cream; it is greater at higher temperatures of churning than at lower ones. As an indication of when the fat is removed as completely as practicable by churning, the size of the butter granules may be taken, though not always. The usual instructions given are to stop churning when the butter granules are about the size of kernels of wheat. This cannot always be relied upon as showing that the churning has been completed, since, under differing conditions, the completeness of separation differs with the size of butter granules. The appearance of the buttermilk is usually a good indication of the completeness of churning; when the fat has been most efficiently removed, the buttermilk should look bluish and thin or watery, an appearance not difficult to distinguish. As a rule, churning should be continued until the buttermilk reaches this condition, without reference to the size of the butter granules. When the churning is most effective, the buttermilk should not contain more than one-tenth of one per cent. of fat.

(2.) Amount of Buttermilk left in Butter.—The larger the granules of butter at the close of churning, the greater the amount of buttermilk remaining in the butter. This is an undesirable condition, since the keeping quality of butter is unfavorably affected by the presence of much buttermilk. Every effort should be made so to control the conditions of cream ripening and the conditions of churning that, when the butter granules are the size of wheat grains, the fat will be removed from the buttermilk as completely as is practicable.

35. Difficulties Experienced in Churning.

It is a common experience, especially in making butter at home, to have churnings in which the fat-globules separate in granules with extreme difficulty from the buttermilk, or refuse to separate at all. Various conditions may cause this behavior. Some of these have already been referred to in connection with the conditions of churning. To some of these we will call more detailed attention at this

point, including (1) the influence of advance of lactation, (2) improper ripening of cream, (3) cream poor in fat, and (4) low temperature of churning.

(1.) Influence of Advanced Lactation.—In the case of cows that are far advanced in lactation, we find a combination of conditions that work against the ease of churning, such as small size of fat-globules, milk-fat of harder character than normal, and a larger amount than usual of albumin, casein and milk-sugar in the milk and cream, thus increasing the resistance offered to the uniting of the fat-globules. In the case of cows that come into milk in the spring, these conditions are noticeable in the winter, when, in addition, the food is often largely dry hay or straw. These conditions may also be aggravated by improper ripening of cream. To overcome the difficulties of churning caused by these conditions, the cows must be given succulent feed, such as silage or roots, and the cream must be ripened so as to develop more than the usual amount of acid. In extreme cases, some additional help may come from diluting the cream slightly with warm water or by adding dilute salt brine.

(2.) Improper Ripening of Cream.—The cream should be ripened under the conditions previously given (see sections 26 to 28, pp. 41-44).

(3.) Cream Poor in Fat.—Usually, it is more difficult to churn completely cream poor in fat. This condition needs to occur only when gravity methods are employed in raising cream. By using the centrifugal method of separating cream, no trouble need ever be experienced in this line.

(4.) Low Temperature in Churning.—In churning at very low temperatures, the agitation mixes air with the cream and the cream often froths or swells. Under these conditions, it is best to let the cream stand several hours and then to warm it up slowly four or five degrees, before trying to churn again. Revolving churns give less trouble in this respect than dash churns. Then, again, in churning at low temperatures, the formation of butter may stop just short of the "breaking" point and not be affected by further churning. In such cases, the difficulty may be overcome by adding a little dry salt to the cream or a little water of the temperature of 85 degrees F. to 90 degrees F.

36. Removing Buttermilk from Granules.

When the churning has been completed and the fat has been gathered into granules successfully, the next step is to remove the buttermilk from the butter. As previously stated, the butter at this stage should be in granules not larger than kernels of wheat, and the buttermilk should be clear and watery in appearance, if the cream has been properly ripened and the churning done

at the right temperature. By the old way, the churning was continued until all the butter was gathered into a fairly solid chunk and was then removed from the churn and the buttermilk was removed by pressure at the same time the salt was worked into the butter. The usual method now is to stop the churn when the butter is still in the granular stage, add a little cold water to favor the separation of the smaller fat-globules still remaining in the buttermilk. The buttermilk is then drawn off from the bottom of the churn and allowed to drain completely, after which water having a temperature of 45 degrees F. to 55 degrees F. should be added in amounts about equal to two-thirds of the buttermilk removed. The water and butter granules in the churn are then greatly agitated, enabling the water to come into contact with every butter granule, care being taken to avoid an amount of motion that will cause the granules to mass in chunks. In about fifteen minutes, this water should be drawn off, the granules allowed to drain thoroughly, and then the operation of washing should be repeated a second time as before. The second wash water should appear clear as it runs away, or, at most, have only a very slight milkiness. If the churning operation has been properly conducted, two washings should suffice to remove the buttermilk. The less washing that is necessary to remove the buttermilk the better. A small amount of salt added to the first wash water aids in removing the buttermilk without salting the butter appreciably. The texture of the butter and the amount of water in it are affected by the manner in which the washing is done, and by the condition of the butter granules.

(1.) Influence of Washing upon Percentage of Water in Butter.—When the butter granules are small and the wash water very cold, more water remains in the butter without appearing in the form of distinct drops than is the case when the granules are larger and the water less cold. If the end of the churning leaves the butter in chunks of the size of a small plum or larger, it is impossible completely to wash the buttermilk out of the butter, and especially if the butter is soft. In such a case, the buttermilk must be removed by working, but can not be done completely even then, and the butter will have a high water content.

(2.) Influence of Washing on Texture of Butter.—The temperature of the water used in washing butter affects the texture of the butter. When butter is soft at the end of churning, and it is hardened by being rapidly cooled down by the addition of large amounts of very cold water, the texture is likely to show the effect of the rapid change of temperature. When thus treated, the outside of the butter granules cools some time before the inside, and if time is not given for complete cooling before it is worked, we have a part of

the butter still soft. In case the butter granules are soft at the end of churning, as the result of too high temperature in churning, the proper method of procedure is to use the usual amount of water at the usual temperature and allow the butter to remain in it, until it has become thoroughly cooled clear through. If treated in this way, it can be worked without risk of getting soft again at once. In addition, the use of large amounts of water in washing butter is apt to remove some of the compounds that give the butter its flavor, producing a flavorless or tallow-like tasting butter.

37. Working Butter.

The real objects in working butter are (1) to mix the salt with the butter and (2) to get the butter into a solid mass suitable for market. Working butter more than is necessary to accomplish these two purposes is not only useless but may be worse than useless when carried to such an extent as to injure the texture or grain of the butter. There is least danger of injuring the grain of butter, when the working is done by pressure, at a temperature of 45 degrees F. to 55 degrees F. The mistake should be avoided of depending upon working to remove moisture, since this is controlled by the size of the butter granules and the temperature of churning. Fine granules and low temperature favor assimilation of moisture.

38. Salting Butter.

The specific purpose for which salt is added to butter is to give taste. The small amount of salt present in butter has little to do with the keeping properties, as only larger amounts of salt have marked antiseptic effect. The one guide upon which to depend as to how much salt shall be added to butter must be the special market in which the butter is sold, in other words, the taste of the consumer. In actual practice, the amount of salt varies all the way from a trace to two and one-half ounces for each pound of butter. The amount of salt preferred by most consumers is three-fourths of an ounce to one ounce of salt for a pound of butter. In some creameries, butter is made for several different markets, requiring all kinds of salting and extreme pains have to be taken to have each kind always uniform. In order to turn out butter of the same uniform quality from day to day, it is essential that the amount of salt retained in the butter shall be the same, or with the least variation possible. It would seem to be a simple matter to control the amount of salt in butter by weighing the drained butter and salting this in proportion to its weight. But the drained butter is not of constant composition from day to day, because the size

of the butter granules and the amount of water clinging to them are not uniform and, hence, the weight of the washed, drained butter granules does not bear a constant, definite relation to the amount of butter when finished. The larger the amount of water in the butter granules, the larger is the amount that will go out on salting and working, and the less will be the amount of salt left in. When the creaming is done by a separator, and a cream of uniform composition is used from day to day, the weight of cream affords a better basis for calculating the amount of salt to use than does the weight of washed butter granules. The salt can be incorporated easily and evenly into the whole mass of butter, if it is added while the water is being pressed from the butter in the worker. It is important to continue the working until the salt completely dissolves, because undissolved particles of salt may cause mottled or streaked butter. A particle of solid salt remaining in the butter may later dissolve in the water contained in the butter and thus form a strong brine at that point, which tends to deepen the color of the butter that comes in contact with this drop of strong brine. Care should be used in the selection of dairy salt, as different brands of salt vary in their fitness for use in salting butter. Generally speaking, good dairy salt should have a uniform size of particles, should be dry and should completely dissolve to a clear solution.

When a small amount of salt is desired in butter, it can be more uniformly and completely incorporated into the butter by using brine instead of dry salt. For this purpose, a brine is prepared by dissolving in warm water all the salt that can be made to dissolve. This brine is cooled to the proper temperature and poured over the butter. The brine may take the place of the second wash water and allowed to stay with the butter about ten minutes, when it is drawn off and a second portion of saturated brine added to the butter for the same length of time. Then the brine is removed and the working done in the usual manner.

39. Packing Butter for Market.

Butter is in condition to pack for market when the salt entirely in solution has been completely and uniformly worked through the butter, and the water in the butter reduced to the desired amount. When butter is to be kept for some time before marketing, it should contain less water than butter intended for immediate use. Popular taste at present appears to call for a comparatively large amount of water in butter when it is consumed fresh. A large amount of water in butter that is to be kept awhile before consumption is objectionable, because sooner or later the water evaporates from the surface, leaving a coating of salt, and the appearance is injuriously affected.

The problem of a perfect butter package yet remains to be solved; that is, a package which is strong, light in weight and air-tight. Packages made of crockery, glass or metal are heavy and liable to be broken. Tin and iron packages rust easily in the presence of the brine. Wooden packages are seldom air-tight. It appears to be the general impression that wooden packages are in all respects the most available. The materials most commonly used are probably ash, spruce and oak. Wooden packages are subject to the disadvantage of imparting their flavor to butter when it is kept in them long. Therefore, great pains must be taken to remove the odor of wooden packages as far as possible before they are used. This may be done by steaming the packages thoroughly and then filling them with hot water, containing some salt. After standing twenty-four hours they are steamed a second time and then filled with cold water.

For direct consumption, butter may advantageously be packed in moulds or prints. The popular demand for this style of package has increased greatly within a few years and its popularity appears to become greater all the while. Prints in pound and half-pound sizes are found in every grocery. The standard size for pound prints is $4\frac{5}{8}$ by $2\frac{1}{2}$ by $2\frac{3}{8}$ inches, and the shape is rectangular. Each print is wrapped separately in parchment paper and special packing boxes are furnished for carrying them.

40. Qualities of Butter.

Certain points have been adopted by common consent to use as a basis or standard in judging of the value of butter. The qualities that have been selected for this purpose are, (1) flavor, (2) texture, (3) color, (4) salt and (5) general appearance. To these may be added (6) moisture and (7) solidity.

(1.) Flavor.—Butter is said to have a good flavor when it possesses the characteristic taste and odor of good butter in a well-marked degree. It is difficult to describe in words what this flavor is, but it is commonly described as a nutty flavor, clean, aromatic and sweet. It should be entirely free from any rancidity or any other unusual flavor. Personal preference forms a very large factor in judging the value of butter in so far as it depends upon flavor. High flavor, for some persons, means sour milk or buttermilk flavor, while, for others, such a flavor must be absent. The real flavor of high-grade butter can be produced only under most favorable conditions of manufacture. Every operation must be conducted with care, and extreme pains must be observed at all times in respect to cleanliness. The one step in the operation of butter-making that has most influence directly upon the flavor of butter is the ripening of

the cream, and too great care can not be taken to have perfect control of this delicate process. Food also exercises some influence. The flavors that are objectionable in butter may come from food, from the absorption of bad odors by the milk or cream, from the action of undesirable forms of bacteria and from excessive amounts of buttermilk retained in the butter.

(2.) Texture.—The texture of butter refers to what is called the grain and depends upon the condition of the butter granules. In its first formation in churning, butter appears in very small, irregular grains or granules. These grains retain their individuality throughout the rest of the process of butter-making and even in the finished product. The more distinct we can keep the individuality of the granules and at the same time make the butter into solid masses, the better is the texture. The granular texture of butter is seen when a mass of butter is broken into parts transversely, giving somewhat the fractured appearance seen in broken cast iron and free from a greasy appearance. Another method of testing the texture is to pass a knife blade or a butter trier through the butter; when it is withdrawn, no particles of butter stick to it. The texture of butter is injured by allowing the butter granules in the churn to become too large, and by working at too high a temperature or too much. The granular texture of butter is entirely and permanently destroyed by warming butter up near to the melting point.

3. Color.—The standard of color for butter is the color given when the butter is made from the milk of a cow feeding upon fresh pasture grass—an even, bright, golden yellow. Just what substance it is that gives butter its natural color, we do not know yet, but we do know some of the conditions that influence its color, such as the breed of cow, character of food and stage of lactation period. Butter tends to become lighter in color toward the end of a cow's lactation period, and especially if the cow at that time is fed exclusively upon dry foods. On fresh pasture, some cows produce butter somewhat too high in color for the critical consumer. Most butter in commerce is artificially colored. There is quite a number of different butter-color preparations in the market, some of which are aniline compounds and are poisonous when used in considerable quantities. If a butter-color is used, it is wise to use annatto or other preparations, which are known to be harmless. When butter is artifically colored, the colored product should be uniform, of a bright, golden-yellow color, free from any reddish tinge. Different shades of color are called for by different markets.

(4.) Salt.—The main point in connection with salt in butter as affecting quality, is that the salt should be entirely dissolved and

distributed uniformly throughout the entire mass of butter. As to the amount of salt in butter, this must be judged entirely according to the standard of the special trade for which it is made.

(5.) General Appearance.—Under this head we include the attractiveness of the package and packing, cleanliness, etc.

(6.) Moisture.—The water should be so completely incorporated with the butter that it fails to show its presence, not appearing in the form of free beads of water.

(7.) Solidity.—By this is meant the quality of firmness or hardness, not melting or softening too easily.

The different qualities indicated above are used in a specific manner for determining the market value of butter, each quality having assigned to it a definite numerical value. The following so-called scale of points is in common use in the markets of this country:

Flavor, 40 to 45.
Texture, 25 to 30.
Color, 10 to 15.
Salt, 10.
Appearance, 5.

41. Composition of Buttermilk.

Buttermilk is the product, containing water and milk solids that remains when fat is removed from milk or cream in the process of butter-making. In general composition, buttermilk resembles skim-milk, containing, like skim-milk, all the constituents of milk, but in different proportions. The amount of fat in buttermilk is of the greatest importance in connection with churning, for only by knowing the amount of fat in buttermilk can we tell with certainty how complete the churning is. So, the buttermilk should always be tested in order to know whether large amounts of fat are being needlessly wasted by being left in the buttermilk. We have already discussed the conditions that affect the amount of fat left in buttermilk, in sections 33 and 34. If the conditions of butter-making are properly controlled, there need not be left in the buttermilk more than one-tenth of one per cent. of fat. Buttermilk from ripened cream differs from that obtained with sweet cream, the former containing less milk sugar, more lactic acid and less milk-fat. The following analysis will serve as an illustration to give a general idea of the composition of buttermilk obtained under the best conditions·

	Per cent.
Water,	90.60
Fat,	0.10
Casein and albumin,	3.60
Milk sugar,	4.40
Ash,	0.70
Lactic acid,	0.60

CHAPTER VI.

THE RELATION OF MILK TO YIELD OF BUTTER.

If we compare the composition of milk with that of butter, we are impressed with the fact that a very small amount of the solids contained in milk, excepting milk-fat, goes into butter. Below we give an illustration showing, under the conditions stated, the distribution of milk-fat through the various operations of butter-making.

42. Distribution of Milk-Fat in Butter-Making.

In the accompanying illustration we assume that we start with 1,000 pounds of milk, containing 4 per cent. of fat; that we produce, in creaming, 200 pounds of cream and 800 pounds of skim-milk, containing 0.10 per cent. of fat; that in churning we produce 155 pounds of buttermilk, containing 0.20 per cent. of fat, and 45 pounds of butter. We will assume also that the mechanical losses of fat amount to 0.30 pound of fat. The following tabular arrangement brings out the manner in which the milk-fat is distributed through these various operations:

	Per cent. of fat in milk.
1,000 pounds of whole-milk contain 40.0 pounds of fat,	100.00
200 pounds of cream contain 39.2 pounds of fat,	98.00
800 pounds of skim-milk contain 0.8 pounds of fat,	2.00
155 pounds of buttermilk contain 0.3 pounds of fat,	0.75
45 pounds of butter contain 38.6 pounds of fat,	96.50
Mechanical losses of fat in various operations, 0.3 pounds of fat,	0.75

Of the amount of fat contained in the whole milk at the start, 98 per cent. went into the cream and 2 per cent. into the skim-milk, 0.75 per cent. into the buttermilk and the same amount was lost mechanically, while 96.5 per cent. went into butter. The total percentage of loss was 3.5 per cent. of the fat originally in the milk.

43. Relation of Fat in Milk to Yield of Butter.

We have seen that it is not milk-serum that produces butter, but it is milk-fat. Hence, if we wish to know the butter-making value of milk, we must know the amount of fat in milk and then we can tell very closely how much butter should be made from 100 pounds of any particular milk. Now, the question arises: "How much butter should be made for each pound of fat present in milk?" Taking the illustration given in the preceding paragraph, we have 1,000 pounds of milk containing 4 per cent. of fat, or 40 pounds of milk-fat, and from these 40 pounds of milk-fat we obtain 45 pounds of butter; that is, for each pound of fat in milk, we make one and one-eighth pounds of butter, or just one pound and two ounces. In this case, we made allowances for losses of fat in skim-milk, buttermilk and handling, which ought not to be exceeded in practice, when the different operations are carried on with proper skill and care. In general, we may lay this down as a fair rule to follow: Each pound of fat in milk should make one pound and two ounces of finished butter.

The question may next be asked, "Why do we have two ounces more of butter than we do of butter-fat or milk-fat?" While we lose a little fat in the operation of butter-making, we add to the milk-fat considerable water and some salt and retain a little casein, so that we not only make up for the fat lost but really add more than enough water, etc., to make up the loss. In the illustration above given, we had 40 pounds of milk-fat to start with, we lost 1.4 pounds in various ways in making butter, leaving for the butter 38.6 pounds of fat, and to this amount of fat we added 6.4 pounds of water, salt, etc., and thus obtained 45 pounds of finished butter. From the foregoing considerations, it can be seen that we need only to know the per cent. of fat in milk in order to calculate the amount of butter to be made from 100 pounds of the milk. It is necessarly only to multiply the per cent. of fat in milk by one and one-eighth or by one pound and two ounces. Thus, we could readily make up a table like the following, covering any range desired:

Per cent. of Fat in Milk.	Pounds of Butter that Should Be Made from 100 Pounds of Milk.
3	3.37 pounds, or 3 pounds, 6 ounces.
3.2	3.63 pounds, or 3 pounds, 10 ounces.
3.5	3.93 pounds, or 3 pounds, 15 ounces.
3.8	4.27 pounds, or 3 pounds, 4 ounces.
4.0	4.50 pounds, or 4 pounds, 8 ounces.
4.5	5.06 pounds, or 5 pounds, 1 ounce.
5.0	5.62 pounds, or 5 pounds, 10 ounces.

44. How to Detect Losses by Yields of Butter.

Ordinarily, one can detect losses of fat in skim-milk and buttermilk by testing them for their fat content. In the absence of such tests, one can make use of the above rule to ascertain how effective one's work is in getting milk-fat into butter. For illustration, suppose we make butter from milk containing 4 per cent. of fat, and get 4 pounds and 3 ounces of butter. From the rule given above, we should get not less than 4 pounds and 8 ounces of butter, so that we have experienced a loss of 5 ounces of butter for 100 pounds of milk. We have either lost extra amounts of fat or we have failed to retain the usual amount of moisture in the butter or have experienced losses in both of these directions. An experience of this kind should move one to discern the causes of loss and then remedy them. In case the amount of butter is greater than is called for by the rule, then we have incorporated an extra large amount of water in the butter.

45. Milk-Fat as a Basis of Paying for Milk at Creameries.

Until a dozen years ago, milk was very generally paid for by weight alone at creameries. This method was based upon the belief that it was milk that made butter and that all kinds of milk were of equal value, pound for pound, in making butter. The next step in the direction of progress was to pay according to the amount of cream raised, measuring it by volume. This was a partial recognition that different milks varied in their butter-producing value. The method of paying for cream was extremely faulty, because the basis of payment was for so many spaces or inches of cream raised in a can of certain depth and diameter. This method assumed that all cream raised by the gravity system contained the same amount of fat and was, therefore, of equal value for making butter. Investigation showed that this assumption was wholly without foundation and was extremely misleading. The next plan put into practice was what was known as the "oil test," by which an attempt was made to measure the butter-producing values of different creams

by actually churning small portions of cream. This plan was found to be open to several objections. Finally, the discovery of the Babcock test, in 1890, furnished a simple means of determining fat in milk or cream. From that time on, the method of paying for milk and cream at creameries on the basis of the fat content gradually spread until now it is probably univesal. The relation of fat in milk to yield of butter is so obvious that only persons lacking in average understanding can fail to appreciate the significance of such relation.

46. Calculating Dividends at Creameries on Basis of Milk-Fat.

Several different methods may be employed to determine the amount of each patron's dividend, when payment is made on the basis of the amount of fat in the milk. There are calculators published that save most of the details in making calculations. Here we present one of the simplest methods, showing all the necessary details. It is essentially the same as the old method in use when the weight of milk alone was used as the basis for payment, while, on the milk-fat basis, it is the amount of fat that is used in making calculations. We will illustrate this method as employed (1) in co-operative creameries and (2) in creameries where milk is purchased for a definite price.

(1.) In Co-operative Creameries.—Taking the time covered by any one dividend, whether a week or month, it is necessary to know (a) the amount of milk delivered by each patron during that time; (b) the per cent. of fat in the milk during the same period of time; (c) the total or gross amount of money received for the butter produced during the same period; and (d) the amount of expenses to be deducted from the gross receipts, such as cost of manufacture, selling, carting, etc. Having these data, we need only to apply the following rule, which is given, for convenience, in three steps.

Rule. Step 1. To find the amount of milk-fat furnished by each patron: Multiply together the per cent. of fat in the milk and the amount of milk delivered by each patron expressed in hundreds of pounds, and decimals of a hundred. This gives the total amount of fat in the milk delivered by each patron during the dividend period

Example:

Name of Patron.	Pounds of milk delivered during dividend period.	Pounds of milk delivered by each patron, expressed in hundreds and decimals.	Per cent. of fat in milk during dividend period.	Pounds af fat in milk delivered by each patron.
A, ...	350	3.50×	4.0=	14.00
B, ...	650	6.50×	3.6=	23.40
C, ...	835	8.35×	5.2=	43.42
D, ...	965	9.65×	4.4=	42.46
E, ...	1,200	12.00×	4.2=	50.40
Total number of pounds of fat delivered by all patrons,	.....	.....	.....	=173.68

Rule. Step 2. To find the net value of one pound of milk-fat:Divide the total net receipts by the total number of pounds of milk-fat delivered by all the patrons during the dividend period. Example:

From the amount of milk delivered by the patrons, as given above, we have made, say, 195 pounds of butter, which realizes 18 cents a pounds, after deducting the cost of making and all other expenses. This will give $35.10 to distribute among the patrons. We now divide $35.10 by 173.68, the total amount of milk-fat delivered by all patrons during the dividend period, and we have 20.2 cents as the net amount of money received from butter for each pound of milk-fat delivered.

Rule. Step 3. To find the amount of dividend due each patron: Multiply together the number representing the pounds of milk-fat furnished by each patron and the net price received for each pound of milk-fat.

In this case, the net price realized for each pound of milk-fat is 20.2 cents, and so we multiply by this the number of pounds of fat delivered by each patron. Example:

Name of Patron.	Pounds of fat in milk delivered.	Net price received for each pound of fat (cents).	Amount of money received by each patron.
A,	14.00×	20.2=	$2 83
B,	23.40×	20.2=	4 73
C,	43.42×	20.2=	8 77
D,	42.46×	20.2=	8 58
E,	50.40×	20.2=	10 18

(2.) In Creameries Where Milk is Purchased.—Under this division come those cases where patrons sell their milk outright for such a price as may be agreed upon. In such cases, a standard may be adopted and milk paid for according to this standard. For example, suppose the proprietor of a creamery agrees to pay at the rate of one dollar a hundred for milk containing 4 per cent. of fat, the price being greater or less than this in proportion as the per cent. of fat is above or below 4 per cent. Paying one dollar for 100 pounds of milk containing 4 per cent. of fat is equivalent to paying 25 cents a pound for milk-fat. Applying this rate to the illustration given above, we have the following:

Name of Patron.	Pounds of fat in milk delivered.	Net price received for each pound of fat (cents).	Amount of money received by each patron.
A,	14.00×	25=	$3 50
B,	23.40×	25=	5 85
C,	43.42×	25=	10 85
D,	42.46×	25=	10 62
E,	50.40×	25=	12 60

CHAPTER VII.

PRELIMINARIES OF CHEESE-MAKING.

As compared with butter-making, the process of cheese-making is much more complicated in its details and difficult to control. It is probably true that our best methods of butter-making are much nearer perfection than are our best methods of cheese-making, but many improvements have taken place in the details of the process of cheese-making during the past twelve or fifteen years. Before the actual operation of cheese-making begins, there are several details which can properly be considered in a separate chapter. We shall, therefore, discuss in this chapter (1) the care of milk by the dairyman for cheese-making, (2) the method of testing milk to detect injurious forms of fermentations, (3) the action of rennet in cheese-making, and (4) the ripening of milk for cheese-making.

47. Care of Milk for Cheese-Making.

In section 13, p. 28, we discussed in considerable detail the precautions to be observed in securing clean milk when the milk is to be sold for direct consumption. All the precautions given there in regard to the conditions of cleanliness to be observed apply with equal force to milk that is to be used for cheese-making. However, in the case of milk intended for cheese-making, after it has been drawn, removed from the stable and strained, we do not need to be so careful in keeping the lactic acid bacteria from growing as we do with milk to be sold for direct consumption. While most of the undesirable forms of fermentation, commonly occurring in milk, may work injury in cheese-making, it is, so far as we now know, very necessary to have more or less lactic acid fermentation in the milk and curd during the cheese-making process, in order to make good cheese, especially in the case of our common type of cheese, the American cheddar. There are two additional points to which special attention will now be called in caring for milk for cheese-making and these are (1) cooling and (2) aerating.

(1.) Cooling Milk.—It is desirable to cool the milk down to the temperature of the surrounding air, or, still better, to 60 degrees F., if it has to be kept long. It is a good plan to assist the cooling by constant stirring. Two objects are thus accomplished. In the first place, in milk thus treated the fat tends to cream less rapidly,

a desirable condition, because in the cheese-making process we want to prevent the separation of the fat from the milk as much as possible. In the second place, the stirring helps any substances with odors to escape from the milk, especially the so-called animal odor and any others that may have been absorbed from the air.

(2.) Aerating Milk.—Stirring milk while cooling is one method of exposing it to the air, that is, aerating the milk. The aerating, as well as the cooling, can be advantageously accomplished by using special forms of apparatus designed for the purpose. The most common form of aerator is a strainer-like tin vessel with holes in the bottom. It is held in position somewhat elevated above the milk can by an iron frame. The milk, as soon as drawn, is strained into this at once and the milk falls in finely-divided drops or streams through the air before going into the can. The Star cooler and aerator allows the milk to flow in a thin film over a corrugated metal surface; the cooling is caused at the same time by having cold water flow through the apparatus. While the more common practice is to cool and aerate only night's milk, it is desirable that morning's milk should be similarly treated. It is also desirable that the two milkings should be kept separate and not taken to the factory in the same can, unless the morning's milk is cooled to the temperature of the night's milk before mixing.

As soon as milk has been cooled and aerated, it should be covered, in order to prevent evaporation from the cream layer. If much evaporation takes place, the layer of cream becomes somewhat tough and does not mix back readily into the milk. This is objectionable for two reasons, (a) the loss of fat is apt to be larger in cheese-making, and (b) it is more difficult to obtain a representative sample for testing. This difficulty usually occurs only with night's milk, but can very easily be obviated.

48. Detection of Injurious Ferments in Milk.

It is extremely important at times to find out whether milk is fit for cheese-making, especially, where troubles have been experienced with fermentations that make it difficult or impossible to produce good cheese. At the Wisconsin Experiment Station a simple method known as the "Wisconsin curd test," has been devised for detecting milks that are undesirable for cheese-making. Specially designed apparatus can be obtained at dairy-supply houses, but is not necessary. The test consists in making a small chunk of cheese-curd from milk in a glass jar. Take pint fruit-jars and perforate the covers with a few small holes. Before using, clean them in boiling water. A sample of each of the milks to be tested is placed in a jar, nearly filling the jar, and the jar is placed in water warmed to

about 95 degrees F. to 100 degrees F. Then ten drops of rennet extract are added to the milk in each jar and the contents are thoroughly mixed. The milk is then left undisturbed until completely curdled, after which it is cut in small pieces with a case knife and stirred in order to expel the whey. Care must be taken to clean the knife each time before cutting the curd in each jar. The whey is poured off at frequent intervals, until the curd mats. The curd is then kept at a temperature of about 98 degrees F. for six or eight hours and then examined. If the milk is good, the curd from it has a solid, firm texture, with only a few small pin-holes, if any. It may have some large, irregular holes caused mechanically by the failure of the particles of curd to unite closely. If gas-forming bacteria are present in the milk, they will produce a curd of spongy texture, very full of holes. Other undesirable fermentations may show their presence by producing a curd of soft, "mushy" texture, while others develop offensive odors. By the use of this test, it is easily possible to detect what patron's milk is the source of trouble, or, in the case of a herd, what individual cow or cows. When unfavorable fermentations are met with in factory experience, this test should be promptly and thoroughly applied, and milk found to be responsible for the trouble should be excluded until its character is improved. Also, milk should not be received for cheese-making when it contains as much as two-tenths of one per cent. of lactic acid. This curd test may also be applied to the examination of market milk that is sold for direct consumption.

49. Source and Properties of Rennet Extract.

We have already (see section 9, p. 22) referred to rennet as containing an enzyme or unorganized ferment, called rennet, which possesses the characteristic property of coagulating or solidifying milk-casein, and, on this account, lies at the basis of our cheese-making. Rennet is used in the form of an extract.

(1.) Source of Rennet Extract.—The usual source of rennet is the fourth stomach of a calf that has not stopped living upon milk. The enzyme is separated from this by special tratment, such as soaking in dilute salt water. For cheese-making purposes, it is much preferable to purchase one of the regular commercial rennet extracts rather than to use a home-prepared article. The best brands of commercial extracts are uniform in strength and free from taints, and this is not commonly true of home-prepared extracts. Rennet extract should be kept in a cool, dark place, if it is to keep its strength for the longest possible time.

(2.) Strength of Rennet in Coagulating Milk.—How powerful the action of rennet is in cogulating milk-casein can be seen in cheese-making ,where we use only one part of rennet extract to five thousand parts of milk, and rennet extract itself is only a dilute form of rennin, the real coagulating substance. One part of absolutely pure rennin can coagulate three million parts of milk. Apparently, rennet extract does not exhaust itself by its own action, but can be used repeatedly. For example, if we could recover from whey and curd the rennet used in coagulating milk, it would coagulate an equal quantity of milk again.

(3.) Chemical Action of Rennet.—When rennet acts upon milk-casein, it changes the composition of the casein, forming a new compound, and this new compound which appears as the coagulated substance is called paracasein. Cheese curd is, then, an impure form of paracasein. This paracasein formed by rennet is quite different from the solid substance formed by milk casein when treated with acids.

(4.) Conditions of Rennet Action.—The conditions of rennet action are quite well understood and we will consider some of them. The rapidity and completeness of coagulation of milk casein by rennet are dependent upon the following conditions:

(a.) Acids Affect Action of Rennet.—Milk must be neutral or acid for action of rennet. If milk is alkaline, rennet will not coagulate it. Increased amounts of acids have a very marked effect in increasing the rapidity and completeness of rennet action in coagulating milk casein. Moreover, very small amounts of acid have a very pronounced influence. For example, a sample of fresh milk that coagulated in 110 seconds was coagulated in 30 seconds when one part of lactic acid was added to 5,000 parts of milk.

(b.) Temperature affects time of coagulation by rennet. The quickness with which rennet coagulates milk increases with increase of temperature. For example, a sample of milk that coagulated at 75 degrees F. in 270 seconds, was coagulated in 65 seconds at 95 degrees F. The character of the coagulated substance also varies with the temperature at which coagulation takes place. Below 60 degrees F. and above 122 degrees F., the curd formed is soft and loose, while at 77 degrees F. to 113 degrees F., the curd is much more firm and solid. The activity or strength of rennet is weakened by heat at 120 degrees F., while heated for sometime above 140 degrees F., rennet becomes permanently weaker or entirely inactive.

(c.) Strength of rennet extract increases rapidity and completeness of rennet action, likewise increased amounts of rennet extract. Dilution of milk by water has the effect of diluting rennet extract and so a given amount of rennet extract acts less rapidly and completely in diluted milk than in the same quantity of milk undiluted.

(d.) Different chemical compounds added to milk affect the action of rennet. For example, many acid salts like free acids, hasten rennet action. Alkaline and alkaline salts prevent it. Rennet coagulation is delayed by common salt, borax, formalin and some other substances used in milk preservatives.

(e.) Heating milk above 150 degrees F. for some time makes it coagulate less quickly with rennet than unheated milk. Milk heated to boiling for some time coagulates either very slowly and incompletely or not at all with rennet. The coagulating power of such milks may be restored by adding small amounts of some acid or by adding calcium chloride.

(f.) Milk from different cows behaves very differently to rennet. For example, in some tests made at the same time and under the same condition with samples of milk obtained from fifteen different cows, the time of coagulation by rennet varied in the individual samples all the way from 50 seconds to 23 minutes. Just why such differences exist no one knows.

50. Methods of Testing Rennet Extracts.

Since different brands of rennet extract vary somewhat in their ability to coagulate milk, it is important to have a means of testing their strength, so that we may know definitely their value. The strength of a rennet extract may be ascertained by finding out how long it takes for a certain amount of extract to coagulate a fixed amount of milk at some definite temperature. The two or three rennet tests in use are based upon this general principle. The two forms in common use are known under the names of (1) the Monrad test and (2) the Marschall test.

(1.) The Monrad Rennet Test.—In this test the amount of milk used is 160 cubic centimeters (about five and one-half ounces fluid measure), and the temperature is 82 degrees to 86 degrees F., and the amount of rennet is one-half of a cubic centimeter, which is diluted to 5 c. c. with water. The apparatus furnished for this test by dairy-supply houses makes these measurements simple. Having the rennet previously diluted, one makes the test as follows: The given amount of milk is heated to 82 degrees to 86 degrees F., 5 c. c. of the dilute rennet solution are added and stirred in quickly with the thermometer. A fixed temperature must be used always; it can be any one point from 82 degrees F. to 86 degrees F., but the point must always be the same one. The time when the rennet is added is noted by the second hand of the watch and then again the time when the milk has coagulated, and then we know how many seconds it has taken for the milk to coagulate. The time when the milk coagulates can be seen more sharply by scattering a few par-

ticles of charcoal on the surface of the milk. The milk is started into motion around the dish by stirring with the thermometer, and the charcoal particles stop the instant the milk curdles. By using a stop watch in carrying out this test, great accuracy and delicacy can be attained. In comparing two rennet extracts by this test, the one that coagulates the milk in the quickest time is the strongest. If possible, the same kind of milk must be used in comparing different extracts. (See Fig. 3.)

(2.) The Marschall Rennet Test.—In this test, the same general plan is followed, but the coagulation takes places in a cup on the sides of which are some graduated lines, while in the bottom of the cup is a glass tube, with very small bore. After the rennet is added to the milk in the cup, this fine glass tube is opened and the milk allowed to trickle away, until the milk coagulates and ceases to run. The marks on the inside of the cup show how much milk has run out and the number of spaces uncovered show the strength of the rennet. The stronger the action of the rennet, the more quickly is the milk coagulated and the less runs out and the fewer spaces are uncovered. There are some objections to this test, which should be noted. A difference in the bore of the glass tube in the bottom of the cup makes a great difference in results, and it is found that the bore differs in different cups. In trying different cups, always compare them on the same sample of milk. While the Marschall test is convenient for ordinary factory work, it is not capable of as great delicacy as is the Monrad test and, therefore, is not so well suited for work requiring extreme precision.

51. Ripening Milk for Cheese-Making.

In ripening milk for cheese-making, the aim is, as in the case of ripening cream, to encourage the fermentation of lactic acid, but in a lesser degree than in cream. Let us first consider how we ripen milk for cheese-making and then how we determine when we have ripened milk enough.

(1.) How to Ripen Milk.—Lactic acid may be formed in milk simply by heating the milk to 82 degrees F. to 86 degrees F., and allowing it to stand awhile. This temperature favors the rapid growth of the lactic acid bacteria already in the milk and the fermentation of the lactic acid takes place quite promptly in ordinary factory milk. There are times, however, when either lactic acid organisms are not abundant or other injurious forms of ferments are so abundant as to repress the growth of the acid-formers, and, under such conditions, it is unwise to wait for the development of the acid bacteria. The method is then to develop lactic acid by adding a starter. A starter prepared as described in section 27, p. 42, may be used, or

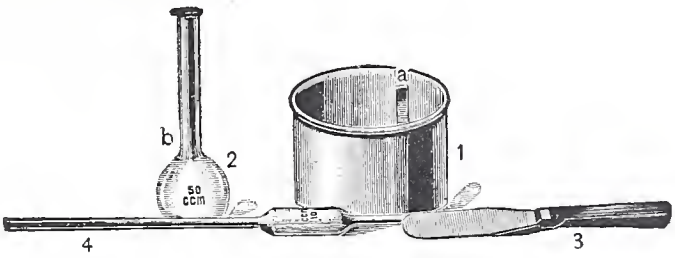

Fig. 3. Monrad's rennet test.

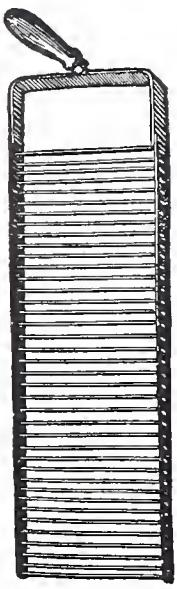

Fig. 4. Horizontal curd-knife.

Fig. 5. Perpendicular curd-knife.

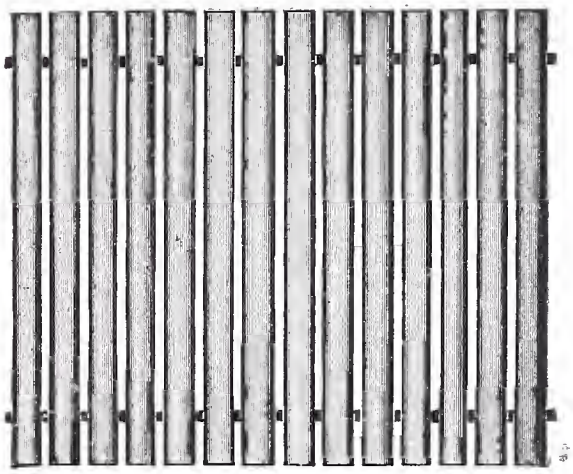

Fig. 6. Curtis improved curd-rack.

Hansen's "Lactic Ferment" can be employed to advantage. The amount of starter to be used in ripening milk for cheese-making should be from two to five pounds of starter for each hundred pounds of milk. The amount will vary according to the temperature of the air and the degree of acidity already in the milk when it comes to the factory. Starters should not be prepared from the mixed milk in the vat or from whey.

(2.) How to Determine the Proper Degree of Ripeness.—Since ripeness in milk means formation of lactic acid, we can measure the ripeness of milk by determining the amount of lactic acid as in the case of cream, but for cheese-making purposes this method is not sufficiently delicate. It has been pointed out above that the activity of rennet is extremely sensitive to the presence of acid; a very minute amount of acid greatly increases the activity of the rennet and reduces the time in which it will coagulate milk. The most satisfactory test for ripeness in milk is to make use of the rennet test in one of the forms described in the preceding section. When milk is found to coagulate by the Monrad test in 45 to 60 seconds, or by the Marschall test in two and one-half spaces, enough acid has developed to enable one to add the rennet for coagulating the milk in the vats. The effect of ripening milk is to hasten the whole operation of cheese-making. The general aim is to have such an amount of acid formed when the rennet is added that the rest of the operation con be completed in six hours. Milk containing as much as two-tenths of one per cent. of lactic acid when brought to the factory is overripe and liable to make trouble in cheese-making. Overripe milk usually causes losses of extra amounts of fat and decreased yield of cheese, since it is difficult for the cheese-maker to control satisfactorily the different operations of cheese-making.

CHAPTER VIII.

MAKING CHEDDAR CHEESE.

There are two methods in use for making the kind of cheese most commonly found in our American markets, (1) the "stirred curd," or "granular" method, and (2) the cheddar method. The latter is probably more extensively used now. The product is essentially the same, though it is claimed for the cheddar system that the texture of the cheese is more solid, and the product more generally uniform, and with a somewhat smaller content of moisture. We shall describe only the cheddar method.

In the chapter preceding, we have prepared the milk for receiving the rennet. The remainder of the process can be advantageously described under the following divisions:

(1.) Coagulating the milk by rennet.
(2.) Cutting the curd.
(3.) Heating the curd.
(4.) Removing the whey.
(5.) Cheddaring the curd.
(6.) Milling the curd.
(7.) Salting and pressing curd.
(8.) Curing cheese.

The subject of cheese curing is so important that we shall reserve its discussion for another chapter.

52. Coagulating Milk by Rennet Extract.

This is also called among cheese-makers "setting the milk with rennet." It may be stated here, that during the process of ripening, the milk should be more or less constantly stirred, in order to mix back the cream that rises or rather to prevent its rising. The milk is heated gradually to 82 degrees F. to 86 degrees F., and then tested for ripeness. If sufficiently ripe the rennet is added at once; if not ripe enough, it is allowed to stand at the given temperature until it gives the right test. However, if the milk is so lacking in acid as to require too long for the acid to form without help, then use a starter as described above. When the amount of acid in the milk is reached according to the tests given above, the rennet extract should be added. Three points in this connection should be considered, (1) the temperature of the milk when the rennet is added, (2) the amount of rennet extract to be added to the milk, and (3) the method of adding the rennet extract.

(1.) Temperature of Milk when Rennet is Added.—There is a variation of a few degrees in the practice of different cheese-makers. The temperature at which the milk is ripened should be the temperature of the milk when the rennet extract is added, and that point may be anywhere from 82 degrees F. to 86 degrees F. The advantage of the higher temperature is more rapid action and economy of time, especially in ripening, if no starter is used. Milk coagulates more quickly considerably above 82 degrees F. to 86 degrees F., but this range of temperature has been shown by experience to be the most desirable. At higher temperatures the curd hardens too rapidly to allow one to cut it conveniently, and in the subsequent process there is greater liability to loss of fat.

(2.) Amount of Rennet Extract to Use.—The amount of rennet extract to use will depend chiefly on its strength, other things being

equal, and this will have to be determined by the cheese-maker with each new lot of extract, employing the regular rennet test. The guide to keep in mind in determining how much rennet to use is this: Use enough rennet to curdle the milk in fifteen to twenty minutes for a quick-curing cheese, and, in thirty to forty minutes, for a slow-curing cheese. The rennet extracts in common use are added at he rate of two and one-half to five ounces for 1,000 pounds of milk, but generally at the rate of from three to four ounces.

(3.) Method of Adding Rennet Extract.—The rennet extract must be diluted with twenty to forty times its own volume of water, which may be cold or at a temperature of 85 degrees F. to 90 degrees F. The object of dilution is to prevent uneven action of rennet on the milk. If undiluted rennet extract is added to a vat of warm milk, the portions of the milk first coming in contact with the rennet coagulates at once before the rennet has a chance to reach the whole body of milk. The diluted extract acts much less quickly and gives one time to mix it uniformly and thoroughly, through the whole mass of milk. Some makers prefer to dilute the rennet with cold water instead of warm, on the ground that the cold water keeps the rennet inactive longer and thus gives a longer time in which to mix the rennet completely through the mass of milk.

Just previous to adding the rennet extract, the milk should be thoroughly stirred, and then the diluted rennet should be poured into the milk evenly from one end of the vat to the other. The milk is at once gently but thoroughly stirred again so as to mix the rennet completely and uniformly with it, and the gentle stirring is continued for several minutes. Then the surface of the milk is stirred quietly with the bottom of a dipper to keep the fat from separating, this movement being kept up for about half the time required to coagulate the milk but stopping before there is any appearance of coagulation. A cloth is then placed over the top of the vat, if necessary, to keep the surface of the milk from cooling, and the milk is kept undisturbed while the coagulation takes place. The rennet does not act instantaneously so as to show any visible signs, the first indication of acting being a slight thickening of the milk, shown by the slowness of drops of milk to fall from a thermometer or other object dipped in the milk and held up so as to allow the milk to drip from it. The coagulation goes on gradually until the whole mass of milk is one solid, continuous chunk of coagulum or curd, the result of changing milk casein into paracasein. In this process, the fat-golbules and also the other milk constituents are imprisoned in the paracasein.

53. Cutting the Curd.

The object of cutting the curd is to permit the whey to go out of the paracasein. This takes place much more rapidly and completely,

in proportion as the pieces of curd are smaller. The paracasein, or curd, as soon as formed, shows a tendency to contract and this shrinking naturally forces out the whey, the liquid portion of the curd. In cutting, the extent of surface, from which the whey can go out, is enormously increased.

(1.) When to Cut Curd.—It is a point of some importance to know just when to cut the curd, as this has considerable influence upon the rest of the operation and upon the amount of fat lost and, so, upon the yield of cheese. If curd is cut when it is too soft, there will be large losses of fat and decreased yield of cheese. If the curd becomes too hard before cutting, the whey is removed less easily, and the quality of the cheese may be injured. The test used to determine when the curd is in the right condition to cut is the following: The end of the index finger is inserted obliquely into the curd half an inch or more and then slowly raised toward the surface; if the curd breaks apart with a clean fracture, without leaving small bits of curd on the finger, and the whey in the broken surface is clear and not milky, the curd is in the right condition of firmness to be cut.

(2.) How to Cut Curd.—In primitive methods of cheese-making, the curd was broken into small pieces with the fingers or with any kind of instrument, and no attention was given to having the small pieces of uniform size or shape. We now have specially devised knives for cutting curd, which leave the curd in small cubes about three-eighths of an inch in diameter. One curd knife is horizontal (see Fig. 4), with numerous parallel blades; the other is perpendicular (see Fig. 5). Cheese-makers differ in their practice in regard to which knife to use first, but it is a matter of little or no importance. In using the horizontal knife, it is carefully inserted into the curd at one end of the vat, care being taken not to jam the curd in so doing, and is then moved along from end to end until the whole mass has been cut. The perpendicular knife is then used at once, cutting not only from end to end of the vat but crosswise also. The movement of the knife should be somewhat more rapid toward the end of cutting. The object to be kept in mind in cutting is uniformity in size of pieces of curd after being cut. In the case of very ripe or over-ripe milk, the curd should be cut finer. The fineness is governed largely by the number of times the knives are passed through the curd.

54. Heating the Curd.

As soon as the curd is cut, the whey begins to go out of it and the curd settles to the bottom of the vat. If it remains undisturbed, the cut surfaces of the curd easily reunite and, when we break them

apart, additional fat is lost. Therefore, as soon as the curd is cut, the whole mass is kept in gentle motion by careful hand-stirring or with a wire basket made for the purpose. Care must be taken to avoid any rough treatment that would crush or break the curd particles, the object of the agitation being simply to keep the particles of curd moving through the whey and thus preventing their settling and matting. Pains must be taken to keep the curd from settling in the corners of the vat or attaching itself to the sides, since, if left in such places, it will be heated too high later. The whey should appear clear and be fairly free from small particles of floating curd. The curd contracts and hardens during this stirring, but the shrinking takes place more quickly upon the outer surface of the curd particles than upon the inside. This hardening of the out surface prevents the curd particles from sticking together so readily, but offers some opposition to the further rapid escape of whey. In order to favor the continuous expulsion of whey, heat is used at this stage. The term "cooking" is commonly applied to this part of the operation, but the word is misleading, since we use only a gentle heat and in no sense "cook" the curd. The object of heating is to favor the contraction of the curd and the escape of whey. The cause of the shrinking of curd is probably due to union of lactic acid with the paracasein, forming a new compound which has the property of contracting. The heat favors the formation of this new substance, and the more rapidly it forms the more readily the curd shrinks and forces out the whey. Heat is applied gradually and the stirring is kept up constantly. Under normal conditions ,the heat is applied so as to raise the tempertaure of the curd and whey about one degree in five minutes, and rarely more than two degrees in five minutes. The heating should be somewhat slower up to 90 degrees F. than above that point, since the shrinking of curd takes place less rapidly below than above 90 degrees F. The contents of the vat should be heated finally to 98 degrees F. As the the temperature is increased, the curd particles become less tender, and toward the end of the heating they can be stirred much more vigorously without risk of injury. When the temperature of 98 degrees F. has been reached, the curd is allowed to settle to the bottom of the vat and remain quiet with only an occasional stirring, until a certain amount of acid has been formed or rather until a certain amount of the compound of lactic acid and paracasein has been formed.

55. Removing the Whey from the Curd.

The whey should be removed from the curd when a certain amount of lactic acid has combined with the curd (paracasein) or, as the cheese-maker commonly says, when there is "enough acid on the

curd." How can we ascertain this? The behavior of the curd will give us this needed information. In the first place, the curd particles should be contracted to less than one-half their original size, and, in the second place, they should be so firm and rubber-like that when a mass of curd is pressed together between the hands and then suddenly freed from pressure, they should fall apart at once, and show no tendency to stick together. During the heating, the particles of curd should be examined occasionally to ascertain whether they are changing on the inside as well as outside. The third sign given by the curd is probably the most useful to go by in deciding when the curd has been heated long enough and when the whey should be removed, and that is what is known as the "hot-iron test." When a small mass of curd, which has been squeezed in the hand to remove whey, is pressed against a bar of iron, heated a little short of redness, and then carefully drawn away, fine, silky threads are formed, adhering to the iron. These strings are caused by the compound of lactic acid and paracasein and the more of this compound there is, the more the curd will string in length. So the hot-iron test is really a measure of the amount of acid that has been formed. Now, when the curd shows, by the hot-iron test, strings one-eighth of an inch long, the whey is drawn from the curd. The removal of the whey is sometimes called "dipping," or "drawing," the whey. When the development of lactic acid has been rapid or promises to be, it may be well, when the curd has reached 98 degrees F., to let it settle and draw off part of the whey, leaving enough to cover the curd two or three inches deep. Then the rest of the curd can be removed when the curd strings one-eighth of an inch. Too much acid at this point must be guarded against, and the whey must be promptly removed when the right point is reached.

56. Cheddaring the Curd.

This operation is the distinguishing feature of the cheddar method. It consists essentially in allowing the curd to mat or pack together in solid chunks after the removal of the whey. The matting process may take place in the vat directly on the bottom or on curd-racks placed in the bottom of the vat or it may be removed to a special apparatus called a curd-sink.

(1.) Matting Curd on Vat-Bottom.—When the bottom of the vat is used, the curd, after the removal of whey, is piled up along the two sides of the vat with an open channel between the two piles of curd to facilitate the running off of the whey that drains from the curd. When the particles of curd have matted together, forming one solid mass, it is cut into chunks or blocks about 8 by 8 by 12 inches; these blocks are then turned over so that the part at first

uppermost comes against the bottom of the vat. Some whey drains out and then the blocks are piled two deep, care being taken to turn in the parts that have been exposed to the air. Later, the curd is re-piled in still deeper piles. This re-piling continues again and again, always observing the precaution to expose to the air the portions that were turned inside on the previous piling. The object of this is to keep the heat uniform through the mass.

(2.) Matting Curd on Curd-Rack in Vat.—In this case racks are used, made of wooden slats, just fitting nicely into the bottom of the vat (see Fig. 6). They are preferably made in four-feet sections. For their use, the vat is tipped and the curd shoved to the lower end. One section of rack is then placed in the empty end of the vat and a linen strainer thrown over it, the strainer being long enough and wide enough to come up over the sides of the vat. Then the curd is piled onto the rack, and broken apart to let the whey escape. After stirring over several times, it is allowed to mat evenly about six inches deep. If needed, the second section can be put in place and used for the rest of the curd, and then the whole is covered with the strainer cloth to keep warm and, if necessary, the whole vat covered with an additional heavy cloth. After ten or fifteen minutes, the curd is matted together, when it is cut into blocks and treated as described above.

(3.) Matting Curd in Curd-Sink.—After most of the whey is removed, the curd and remaining whey are dipped into the curd-sink and allowed to drain. Then proceed to mat, cut, pile and re-pile as stated above. All things considered, the use of a curd-sink is advantageous.

Piling curd has a tendency to make a quick-curing, soft cheese. If a slow-curing cheese is desired, the curd should be piled only a little or none at all, the blocks being simply turned over and over in a single layer. A curd from very ripe milk should not be piled much.

Cheddaring, or matting curd, accomplishes two results. First, the whey is expelled to a considerable extent and, second, the lactic acid unites with more of the curd, thus changing not only the chemical composition but the physical condition of the curd. From a spongy, tough, rubber-like consistency, with a high water content, the curd changes to a mass having a smooth, velvety appearance and feeling, and a softer, somewhat plastic, consistency. The texture also changes so that the curd acquires a peculiar fibrous condition or grain, tearing off somewhat like the cooked meat of a chicken's breast. Then, in addition, owing also to the increase of the compound formed by the curd with lactic acid, the curd forms longer strings on a hot iron, probably an inch or more after the

cheddaring has continued some time. Usually, when the curd strings one inch and the other physical appearances of the curd are as described above, the curd is ready for milling.

57. Milling the Curd.

Milling curd consists simply in cutting it into small pieces in order to salt it and handle it conveniently in putting it into hoops for pressing into a solid mass. Several mills are on the market for this purpose. The best machines cut the curd into pieces of uniform size, without tearing it in pieces. When properly milled, there is less loss of fat and the curd is more evenly salted. After milling, the curd is piled up to flatten out the pin-holes and then stirred enough to keep it from matting together, perhaps every fifteen minutes. The time for milling should come about half way between removing the whey and salting the curd. The breaking down or softening of the curd continues after milling, as a result of further formation of lactic acid and its combination with the paracasein of the curd. When the curd forms strings on a hot iron about two inches long, it should be salted. During all this time the curd should be kept warm.

58. Salting and Pressing Curd.

(1.) Salting.—Salt is added to curd chiefly for the flavor it imparts, but the presence of the salt produces several other effects. It aids in removing whey; it hardens the curd; it checks or retards the formation of lactic acid. In the absence of salt a cheese cures more rapidly and is apt to develop a bitter flavor even at moderately low temperatures. Excessive salting makes a cheese mealy because too dry and the cheese cures very slowly.

A salt of fairly coarse grain is preferable for cheese, because it dissolves more slowly and reaches farther into the pieces of curd. When the salt is added, the curd is spread out thin in order to cool to 90 degrees F., and the salt is mixed uniformly through the curd. Then the curd is stirred until the salt is completely dissolved. In respect to the amount of salt to use, the usual amount is two and one-half ounces to three pounds of salt for the curd made from 1,000 pounds of milk. A moist curd should be salted somewhat more.

(2.) Pressing.—Before pressing, the curd should be cooled to a temperature between 78 degrees F. and 84 degrees F. If put in press warmer than this, the fat runs out and is lost and it also prevents the pieces of curd sticking together perfectly. If curd is put in press much below 80 degrees F., the pieces do not cement com-

pletely and so fail to form a solid mass. The main object of pressing is to give the cheese a definite form for market and not to squeeze out whey, though this is done to some extent. The whey should be removed from the curd while it is in the vat. No amount of pressure can make up for failure to remove the whey at the proper time. If the process has been properly carried on so as to form a proper amount of the compound of lactic acid and paracasein, and if the temperature of the curd, when put in the press, is not much below 80 degrees F., a comparatively light pressure will be sufficient to cause the pieces of curd to cement together in a smooth, uniform and solid mass. The pressure should be uniform and continuous for twenty-four hours. When a screw press is used, the pressure must be applied gradually at first and care must be taken, especially during the first hour of pressing, to tighten the screws as quickly as they become loose.

When the cheese has been in press about one hour, it is taken out, turned, the bandage straightened and the entire surface of the cheese wiped with a cloth wrung out of hot water. Seamless bandage is used, being cut long enough to extend over the edges on both ends of the cheese one and one-half to two inches. When the cheese is put back in press, circular cloth caps are put on between the ends of the cheese and the follower and are allowed to remain.

59. Some Common Troubles of Cheese-Making.

The conditions of temperature present during the cheese-making process are extremely favorable to the growth of many kinds of bacteria and, when certain kinds are present, we have undesirable forms of fermentation, producing abnormal behavior in the curd and defective cheese.

(1.) Gas-Forming Fermentations.—One of the common troubles in cheese-making is a "floating," or "gassy" curd. This fermentation produces gas in the curd and bubbles of gas cause the curd to swell, filling it with small holes, so that it becomes very spongy. When the gas is sufficiently abundant, it makes the curd light enough to float on the surface of the whey. The small gas holes can easily be seen inside the pieces of curd by cutting across them. They are usually known as "pin holes," forming a "pin-holey" curd. The source of this fermentation is commonly lack of cleanliness on the part of one or more patrons, and the different milks should be tested by the curd test (see Section 48, p. 64), in order to detect the offending party. However, if one is suspicious of the presence of such fermentations in the milk, they can usually be prevented or lessened by abundant use of a starter, developing abundance of lactic acid in the curd. It has been found that these gas-forming

bacteria do not usually develop in the presence of vigorous lactic acid fermentation. The milk is well ripened before adding rennet and the temperature used in heating the curd is raised somewhat more rapidly and two to six degrees higher than usual. The curd is kept warm after removing whey and the escape of gas is favored by frequent turning and re-piling of the curd, thus closing the pin holes. The gas-forming fermentations often produce offensive-smelling gases. When these are present in curd, they may be washed out by drenching the curd with hot water. When a floating or spongy curd is not properly treated, the resulting cheese is defective in texture and flavor, and even when these defects are prevented, there is extra loss of fat and of cheese yield. Prevention by cleanliness is the best method of treatment.

(2.) Over-ripe Milk.—In some cases, especially in hot weather, the milk may have developed too much lactic acid and be on the verge of souring when brought to the factory. When there is so much lactic acid at the start, the changes in the curd take place much more rapidly than usual, or, as the cheese-maker says, the curd "works fast." Under these conditions, the whey does not escape from the curd rapidly enough, that is, the curd has not shrunken enough when it comes time to remove the whey. Under these conditions, the curd is constantly and thoroughly stirred after the whey is removed and the whey is thus well worked out before the cheddaring begins. When it is known at the beginning that the milk is over-ripe, the milk should not be heated to the usual temperature before adding rennet, and a larger amount of rennet is used. After cutting, the curd is stirred until the whey is well separated before applying additional heat.

60. Sizes of Cheese.

The sizes in which cheeses are made depend upon the special market in which one's product is sold. The most common size is 15 inches in diameter and weighs from 60 to 65 pounds. Cheeses of the same diameter and one-half the weight are known as "flats." Other sizes are 13 and 11 inches in diameter. Cheeses 7 inches in diameter are known as Young Americas, usually weighing 8 to 10 pounds.

CHAPTER IX.

CURING CHEESE—QUALITIES OF CHEESE.

The importance of care in managing cheese after it is made has been seriously overlooked. Until quite recently, little attention has been given to methods of cheese-curing in this country. The rule has been and still is, in too many cases, to place the cheese in some room in the factory that is provided with no means of controlling temperature and moisture, where the variations in these factors follow the conditions existing out of doors. It is now being realized that the best-made cheese may be absolutely ruined for market by lack of care during the curing process. The curing of cheese is a part of the manufacturing process and must not be slighted any more than any other important step.

61. Changes Caused by Curing Cheese.

It is well known that cheese must have age before it is salable for consumption. What takes place in cheese while it is acquiring age, that is, while it is curing or ripening? Several different changes occur, which we will briefly notice.

(1.) Loss of Moisture.—It is well known among cheese-makers that cheese begins to lose weight immediately from the time it is taken from press and placed upon the shelves of the curing room, and this loss continues for a long time. The rapidity and extent of loss of moisture in cheese during the process of curing vary with several conditions, such as (a) the percentage of moisture originally present in the cheese, (b) the texture of the cheese, (c) the size and shape of the cheese, (d) the temperature of the curing room, and (e) the proportion of water vapor present in the air of the curing room. The more moist a cheese is when first made, the more rapidly it loses moisture. Cheese with spongy texture loses moisture more rapidly than does cheese with perfect texture. Large cheeses lose moisture less rapidly in proportion to their weight than smaller cheeses. "Flats" lose weight more rapidly than cheeses of the same diameter and twice the height. The higher the temperature of the curing room the greater the loss of moisture. The greater the moisture in the air of the curing room the smaller is the loss of weight.

(2.) Changes in the Paracasein.—In freshly coagulated cheese-curd, the milk-casein has been changed to paracasein, and, with the formation of lactic acid in cheese, the paracasein unites with the acid forming a new compound. Fresh cheese has always been supposed to consist entirely of paracasein, except for the fat, moisture and salt. It has recently been discovered in the laboratory of the New York (Geneva) Agricultural Experiment Station that fresh or green cheese instead of containing paracasein, contains the lactic acid compound of paracasein. Now this compound undergoes changes in the course of ripening, which greatly change the whole character of the cheese. Green cheese is tough, somewhat rubber-like, not appreciably soluble on the tongue, difficult of digestion, and lacking flavor. In the course of ripening, the cheese becomes more or less soft, more easily digestible and acquires characteristic flavors. A piece of well-cured cheese, when placed on the tongue, should dissolve somewhat like a piece of cold butter, leaving no trace of harsh or gritty-feeling particles. Just how the flavor is produced or where it comes from we do not know with certainty. In normal cheese-ripening, the fat undergoes little or no change. The curing process in cheese involves the change from unmarketable to marketable conditions. The exact causes of these changes are not clearly known yet; it is probable that they are due to the combined action of galactase, the enzyme in milk, to the pepsin enzyme in rennet, and to certain forms of bacteria.

62. Temperature for Curing Cheese.

It has been found that cheese cures more quickly at higher temperatures and that, above certain temperatures, the texture and flavor are unfavorably affected. It was formerly thought that a temperature of 70 degrees F. was about right for best results. But it is now known that a temperature of 55 degrees F. or 60 degrees F. gives very much better results, and it is thought that a temperature as low as 40 degrees F. may be still better. Cheese cured at 75 degrees F. or above will suffer more or less from leakage of fat. It may be said with positiveness that cheddar cheese cured above 60 degrees F. does not give cheese of the best quality, either in respect to general character or in respect to keeping qualities. Cheese cures more slowly at lower temperatures, but the product is superior in quality. In addition, at low temperatures, less moisture is lost and one has more pounds of cheese to sell.

63. Moisture in Air for Curing Cheese.

The relative amount of moisture in air can be shown by an instrument (see Fig. 7), called a hygrometer, or hygroscope, which can be

purchased at dairy-supply houses. The relative amount of moisture for a curing room for cheddar cheese is from 65 to 75 per cent; the nearer the latter figure the better.

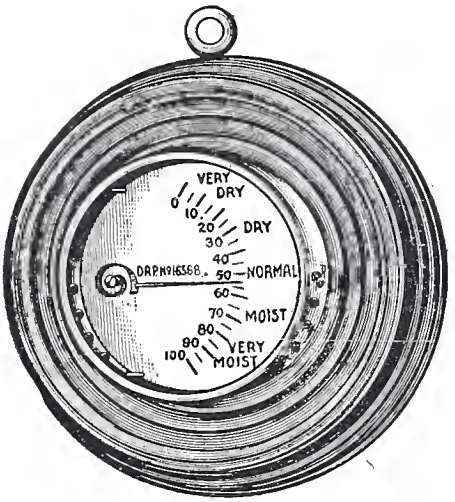

Fig. 7. Hygrometer.

64. How to Control Moisture and Temperature in Curing Rooms.

Ordinarily, each factory must provide for itself a suitable kind of curing room, if it cures its cheese properly. Of course, cheese may be sold and removed from the factory before it is a week old and the whole process of curing placed in the hands of the buyer, who will gain the benefit of the increased value of the well-ripened cheese. This, however, is better than keeping cheese at the factory and spoiling it. In some cases several factories may unite to build a central curing-house, to which the cheese, while still green, can be removed from the factory. But, in many cases, the factory is the place where the curing-room will have to be built if anywhere.

The following statements are, for the most part, condensed from Prof. F. H. King's Wisconsin Bulletin No. 70. The cuts are from the same source.

Curing-rooms may be constructed above ground or under ground and may be of wood or masonry, or a combination. Considering moderate cost, convenience and efficiency, a curing-room built of wood entirely above ground is the most practicable for the average factory.

(1.) Location.—A curing-room above ground should be placed on the north side of a building in order to be protected as much as possible from the direct rays of the sun. It is advantageous also if the room can be shut off on the other three sides by hallways, stairways other rooms or building screens.

(2.) Windows in a curing-room should be as few and as small as consistent with the amount of light necessary. They should be made double, as nearly air-tight as possible, and preferably in one section, fitted closely and permanently in place. If necessary to exclude direct sunshine, blinds or awnings should be placed outside.

(3.) The door of a curing-room should be built to resemble that of a refrigerator.

(4.) Walls should be built like those of cold-storage and ice-houses. The studding outside should be covered with matched sheathing and drop siding, with a layer of three-ply acid and water-proof paper between. The paper recommended by Prof. King is manufactured

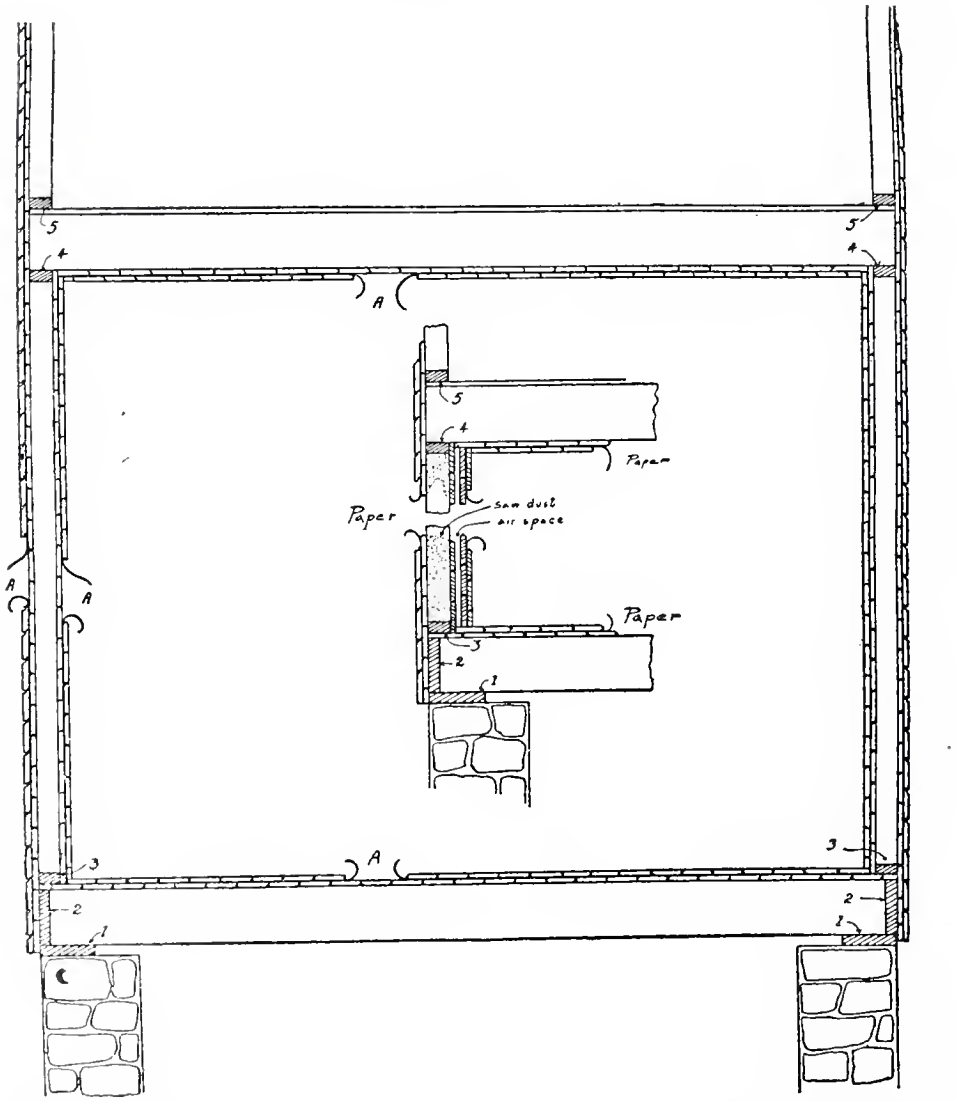

Fig. A. Showing the construction of wood curing-room. 1, 1, 1, sill; 2, 2, 2, a two-by-ten spiked to ends of joist; 3, 3, 3, a two-by-four spiked down, after first layer of floor is laid, to toe-nail studs to; 4, 4, 4, a two-by-four spiked to upper ends of studding of first story. A, A, A, A, three-ply acid and water-proof paper. The drawing in the center shows space between studding filled with saw dust and another dead-air space to be used when the best ducts cannot be provided.

(From Wis. Agr. Exp. Sta. Bul. 70.)

by the Standard Paint Company, New York and Chicago. In the inside a layer of matched sheathing is nailed to the studding, then strips of inch furring two inches wide, to which are nailed two thicknesses of matched sheathing, with paper between. The outer air space between the studding is filled with sawdust or similar material and the spaces left by the furring are closed air-tight at the ceiling and floor. (See Fig. A.)

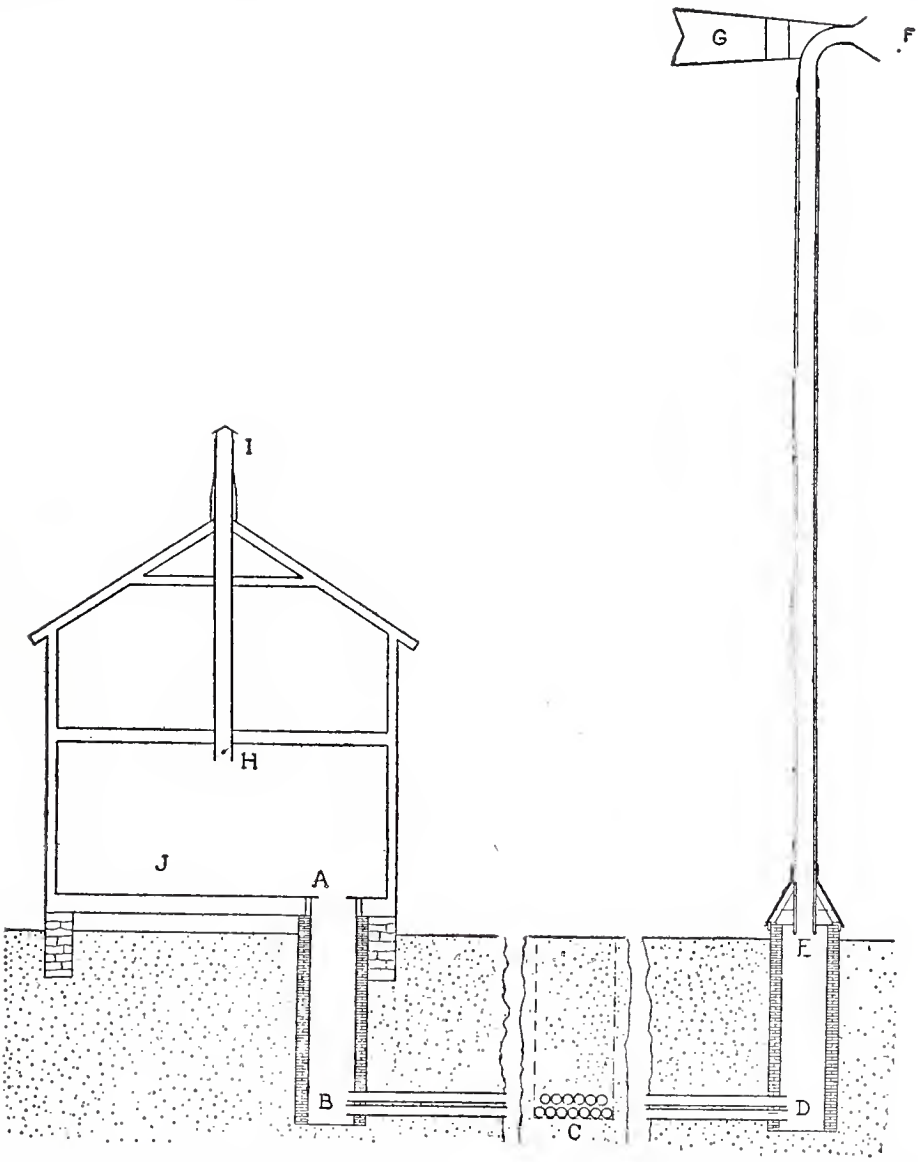

Fig. B. Section of cheese-curing room and horizontal multiple sub-earth duct. A, inlet to curing room; B, end of sub-earth duct in bricked entrance to factory: C, cross-section of the multiple ducts; D, E, bricked entrance under funnel at outer end of sub-earth duct; funnel with mouth 36 inches across; G, vane to hold funnel to the wind; H, ventilating flue with damper.

(From Wis. Agr. Exp. Sta. Bul. 70.)

(5.) Ceiling and floor should also consist of two thicknesses of matched lumber with paper between, and joints made at corners should be very tight.

In constructing curing-rooms two things should be kept in mind; first, that the walls should be as nearly air-tight as possible in order to keep out the warmer air outside and, second, that the walls should be poor conductors of heat. It is advantageous to cover the inside walls with two coats of shellac.

(6.) Ventilating flue in ceiling.—It is desirable to provide a tight ventilating flue in the ceiling of the curing-room, extending above the roof. Its diameter may be six to eight inches. It should be provided with a damper. (See Fig. B, H, I.)

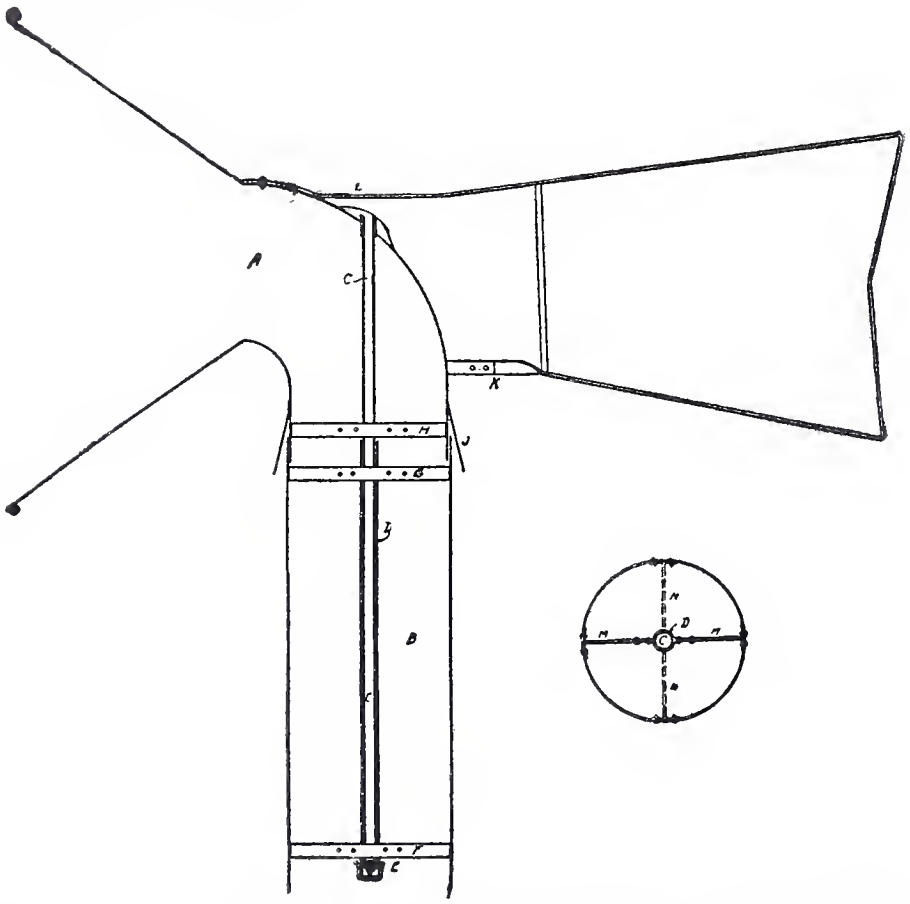

Fig. C. Showing how the funnel and vane may be mounted. A, funnel; B, shaft of funnel; C, C, C, 1-inch gas pipe; D, D, 1¼-inch gas pipe; E, cap for support of 1-inch gas pipe; F, G, H, and M M and N N are stays of band iron bolted together and to the sides of the shaft to support the axis of the funnel; J, weather collar to turn rain out of shaft. K, L, band-iron to stiffen vane and attach it to funnel.
(From Wis. Agr. Exp. Sta. Bul. 70.)

(7.) Methods of Controlling Temperature and Moisture in Cheese-Curing Rooms Placed Above Ground.—After constructing a proper curing-room, it is essential to provide arrangements for controlling temperature and moisture. The construction of a curing-room is only a partial means toward this end. The following methods have been found effective in keeping the temeprature during summer between 58 degrees and 70 degrees F. and at the same time modifying

the moisture content of the air favorably: (a) Ventilation by air forced through horizontal sub-earth ducts or deep vertical sub-earth ducts and wells. (b) Ventilating over ice. (c) Evaporation of water.

Fig. B illustrates the construction of a horizontal sub-earth duct, which should be twelve feet or more below the surface of the ground and 100 feet or more in length. It is recommended that the sub-earth duct of three rows of 10-inch drain tile laid side by

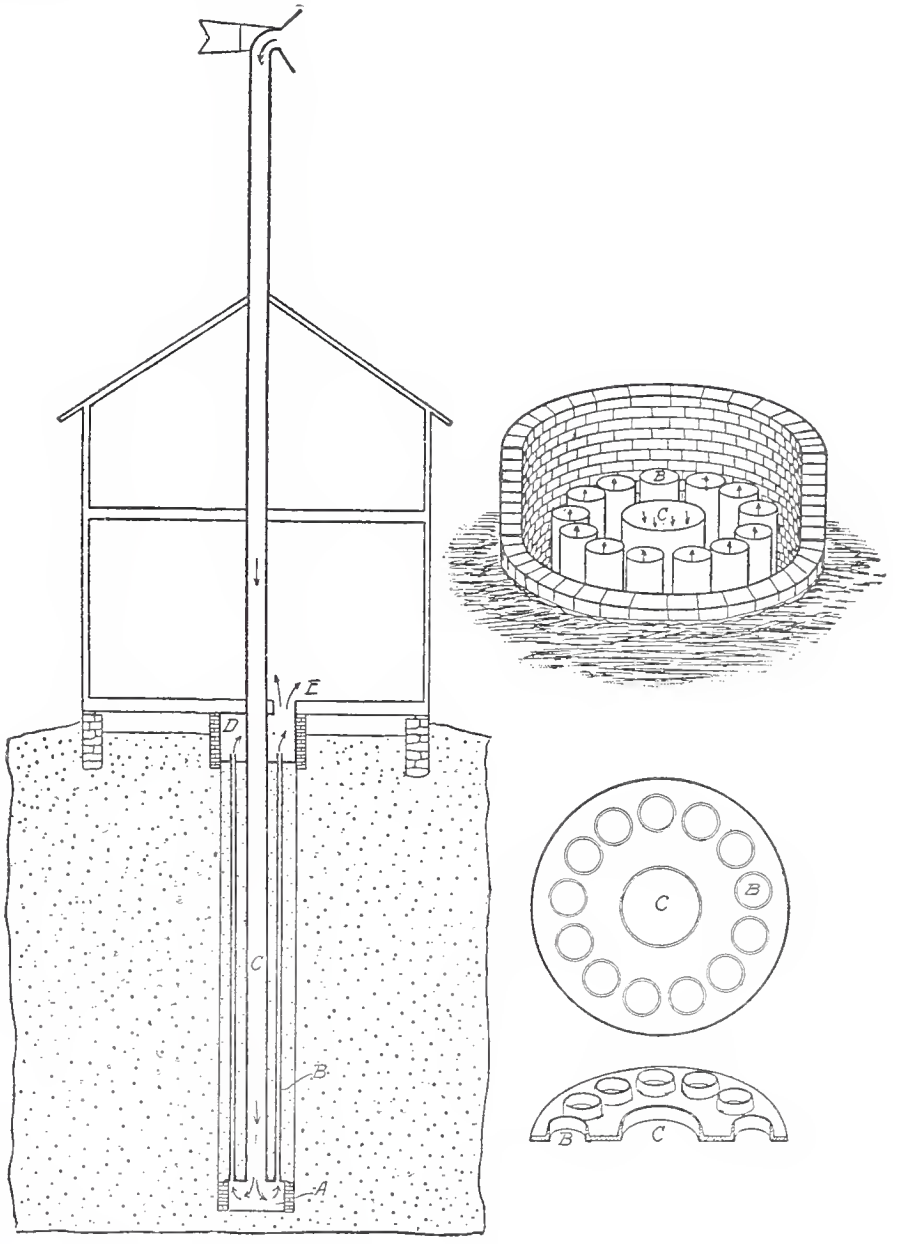

Fig. D. Showing vertical sub-earth duct. A, brick chamber 25 to 30 feet below surface and 40 inches inside diameter; tile or conductor pipe of galvanized iron; C, main shaft of funnel; D, brick chamber at upper end of duct. The circle and section represent a cast-iron plate to cover brick chamber A, and can be had of King & Walker, Madison, Wis.

(From Wis. Agr. Exp. Sta. Bul. 70.)

side at the bottom of the trench, or the trench may be dug narrower and one or two feet deeper and the tile placed one above the other. The shaft for carrying the funnel must be made tight; it may be twelve inches square, if made of plank, or twelve inches in diameter, if made of galvanized iron. The height should be sufficient to enable the funnel to catch the wind readily. The construction and mounting of the funnel are illustrated in Fig. C. The extreme diameter of the funnel should be about thirty-six inches.

The inlet from the sub-earth duct into the curing-room must be provided with some arrangement of valves that will permit the air to be shut off wholly or partly. Too rapid entrance of air in warm weather will not permit enough cooling during passage through the duct. In case of dry winds, too rapid entrance would reduce the moisture too much.

In Fig. D there is illustrated a deep vertical sub-earth duct. Such a duct has the advantage of requiring less piping and also less wind will suffice to produce a current of air. The vertical duct should have a depth of not less than twenty-five or thirty feet, provided water is far enough from the surface. Thirteen lines of 6-inch drain or 5-inch galvanized iron conductor pipe may be used and placed as in the cut. The duct should be located near the north end of the curing-room or directly beneath it. A hanging platform can be used in placing the pipes or tubes in position and the earth packed carefully around the pipes. An excavation of proper size, made as for an ordinary well, will answer the purpose. After the duct has been placed in position, the earth that has been removed can be used for filling around the duct.

In Canada, considerable work has been done in using ice in curing rooms to control temperature. Where ice can be obtained conveniently and cheaply, this method may be advantageously utilized. One or more ice boxes are placed in the curing-room, so built that air can circulate about the ice and into the curing-room. Also compartments, filled with ice, may be made adjoining the curing-room on the side or above, provided with openings into the curing room which will allow a flow of air over the ice and into the curing-room.

Where special means are needed to secure moisture, this can be effectively done by means of yard-wide strips of any cloth material that has good capillary power. The pieces of cloth are hung about the room and kept more or less saturated with water. Experience will tell how much evaporating surface is needed to provide the degree of moisture needed.

65. Qualities of Cheese.

Certain qualities of American cheddar cheese have been adopted as a basis in judging of the commercial value of one cheese as com-

pared with another. The terms used in expressing these qualities are the following: (1) flavor, (2) body, (3) texture, (4) color and (5) general appearance.

(1.) Flavor.—By flavor, as applied to cheese, we mean the odor of the cheese, or really odor and taste combined. The sense of smell is, as a rule, more sensitive in detecting variations of flavor in cheese than the sense of taste. Flavor in cheese is said to be perfect when it resembles that of first-class butter, with an added something of its own that can not be described. The proper cheese flavor should be marked but not strong. The flavor should be free from all other flavors, referring particularly to the more or less offensive products of undesirable fermentations. The taste should be mild and somewhat lasting, but not be so sharp as to "bite" the tongue.

Tainted flavors are numerous in kind and name. They may resemble the odor of the cow or the stable; others are characterized as "sweet and sickish;" others suggest the odor of rotten eggs, and others putrefactive smells. There is the "off" flavor of rancid butter, produced by too long keeping under improper conditions. This list is far from exhaustive.

(2.) Body.—This term, as used in reference to cheese is not easy to define; it means about the same as substance. A cheese is said to have a perfect body when it is solid, firm and smooth in substance. This quality is ascertained by pressing cheese between the fingers. The body is said to be solid and firm, when it shows a certain amount of resistance under pressure, somewhat like that of a piece of fat pork. When it does not press down readily and is tough, the body is said to be "corky." The body is said to be smooth when, under pressure between the thumb and fingers, it feels smooth and velvet-like, as opposed to harsh or gritty or mealy. The firmness of body may be diminished by excessive moisture or by large amounts of fat relative to paracasein compounds, while the smoothness may be increased. The harsh or gritty feeling in cheese may be produced by removal of fat from milk, by excessive acidity in milk, by too much salt, or by any condition that retards or prevents the normal ripening of the cheese.

(3.) Texture.—Texture, as applied to cheese, refers mainly to compactness. Usually the body is considered as a part of texture, but the two qualities are usually quite distinct. The texture may be fine and close or porous. The texture is perfect when a cut surface of the inside of the cheese presents to the eye a solid, compact, continuous appearance, free from breaks, holes and chunks. A porous texture of any kind is imperfect. When a plug is drawn from the cheese, it should be smooth and not "fuzzy." When the

plug is broken in two, it should not crumble, but show a flaky appearance, termed a "flinty break," resembling the surface of broken cast-iron or broken flint. Cheese should show no visible or separated moisture and no fat, separate from the main body of the cheese.

(4.) Color.—Cheese, whether artificially colored or not, should be uniform in color and free from any mottled appearance. When held between the eye and the light, it should be slightly translucent.

(5.) General Appearance.—The rind of cheese should be smooth, free from cracks, and fairly hard. The bandage should be smooth and neatly and uniformly rounded over the edges about two inches on each end of the cheese. The sides of the cheese should be straight and of uniform height all around. The following scale of points is in use in judging cheese according to these qualities:

Flavor, 45 to 50.
Texture, 30 to 35.
Color, 10 to 15.
General appearance, 5 to 15.

CHAPTER X.

THE RELATION OF MILK TO CHEESE.

For a long time, attention was so completely absorbed by methods of cheese-making that very little was accurately known up to ten years ago about the general principles underlying the methods employed. Less than a dozen years ago we were completely in the dark in regard to such fundamental facts as the relation of fat and casein in milk to yield and quality of cheese, the character and extent of losses of milk constituents in cheese-making, their causes and remedies, the influence of removing fat from milk upon the composition of cheese, and in general, the detailed relations existing between cheese and the material from which it is made.

66. Relation of Composition of Milk to Yield of Cheese.

Not many years ago there was a widely prevalent, if not universal, belief that all kinds of milk were practically of equal value for the purpose of making cheese. This belief was based upon two assumptions, (1) that it is impossible to retain the fat of milk in cheese when the milk-fat exceeds $3\frac{1}{2}$ or 4 per cent., and (2) that the amount of casein is practically the same in all kinds of milk. What are the actual facts?

(1.) Proportion of Milk-Fat Lost in Cheese-Making in Different Milks.—Careful and extensive investigations have shown clearly that the amount of fat lost in the process of cheese-making varies comparatively little whether the milk contains more or less fat. The following tabulated summary represents averages obtained with a very large number of experiments carried on by the writer with normal milk varying in fat content from 3 to over 5 per cent.:

[illegible]	Pounds of fat in 100 pounds of milk.	Pounds of fat lost in whey for 100 pounds of fat in milk.	Per cent. of fat in milk lost in whey.
One,	3 to 3.5	0.32	9.55
Two,	3.5 to 4	0.33	8.33
Three,	4 to 4.5	0.32	7.70
Four,	4.5 to 5	0.28	5.90
Five,	5 to 5.25	0.31	6.00

An examination of the figures in the third column, shows that about the same amount of fat is lost in the whey for one hundred pounds of milk, whether the milk contains 3 per cent. or more of fat. Looking at the figures in the last column, we see what proportion of the fat in milk is lost in the whey. Thus, when the milk contains 3 to 3.5 per cent. of fat, 0.32 pound of this fat is lost for 100 pounds of milk, which is 9.55 per cent. of the amount of fat in the milk. The proportion of fat grows actually less as the milk becomes richer in fat. As a rule, the loss of fat in cheese-making is quite independent of the amount of fat in milk.

(2.) Amount of Casein in Different Milks.—In regard to the second assumption made above, that the amount of casein is practically constant in all kinds of milk, we can say that our work and the work of others does not justify the statement. As a rule, when fat in milk increases, the casein also increases, though not in quite the same proportion. Above 4.5 per cent. of fat, the casein appears to increase less rapidly than in milks containing less than 4.5 per cent. of fat. In the tabulated data given below, one can see about how fat and casein are related to each other in milk containing different amounts of fat:

Per Cent. of Fat in Milk.	Per Cent. of Casein in Milk.
3	2.10
3.25	2.20
3.50	2.30
3.75	2.40
4.00	2.50
4.25	2.60
4.50	2.70

In general, when the fat increases one-fourth of one per cent., the casein increases about one-tenth of one per cent..

Now, we wish to make use of the foregoing facts in showing that the composition of milk does necessarily influence the yield of cheese.

(3.) Increase of Cheese Yield with Increase of Fat in Milk.—We must bear in mind that the two solid constituents of milk which are chiefly concerned in making cheese are fat and casein. We have just seen that when milk grows richer in fat it also grows richer in casein, and richer milks therefore contain larger quantities of the materials that make cheese. Since the yield of cheese depends primarily upon fat and casein, and since these costituents vary in milk, it must follow that the cheese yield depends upon the composition of the milk, varying as the fat and casein in the milk vary. In the following table, we give the approximate yield of cheese for milk containing different amounts of fat, varying from 3 to 4.5 per cent.

Per Cent. of Fat in Milk.	Pounds of Cheese Made from 100 Pounds of Milk.
3	8.55
3.25	9.10
3.50	9.60
3.75	10.10
4.00	10.65
4.25	11.20
4.50	11.70

These figures show that as milk grows richer in fat the same amount will make more cheese. In average cheese-factory milk, the approximate amount of green cheese can be found by multiplying the per cent. of milk-fat by 2.7.

67. Losses of Milk Constituents in Cheese-Making.

What constituents of milk are normally lost in cheese-making? What amounts are to be regarded as normal losses? What causes the necessary losses? What conditions produce unnecessary losses?

(1.) Cheese-Producing and Whey-Producing Solids in Milk.—Of the milk constituents, most of the water, albumin and sugar goes in to the whey, with more or less of the mineral constituents, together with small amounts of fat and casein. We may, therefore, call the albumin and sugar and water whey-producing constituents, while the casein and fat are cheese-producing constituents. Of course, some water and small amounts of albumin and sugar go into the cheese. In the following table we illustrate how these different constituents of milk are distributed in the whey and cheese:

Table Showing Distribution of Milk-Constituents of 100 Pounds of Milk in Whey and Cheese.

	Pounds.	Pounds of water.	Pounds of milk-solids.	Pounds of fat.	Pounds of casein.	Pounds of albumin.	Pounds of milk-sugar.	Pounds of ash.
Milk,	100	87.00	13.00	4.00	2.50	0.75	5.00	0.75
Whey,	89.35	83.00	6.20	0.30	0.10	0.72	3.50	0.72
Cheese,	10.65	4.00	6.70	3.70	2.40	0.03	1.50	0.03

On an average, 49.5 per cent. of the milk solids goes into the whey, and 50.5 per cent. into the cheese. In poor milks, a larger proportion of the solids goes into whey; in rich milks, a larger proportion goes into cheese; in other words, milk rich in fat contains a larger proportion of cheese-producing solids than does milk poorer in fat. Put in another way, of the solids contained in 100 pounds of average factory-milk, about 6.25 pounds go into whey and 6.50 pounds into cheese.

(2.) Loss of Milk-Fat in Cheese-Making.—For 100 pounds of milk, there is lost in whey in cheese-factory work from 0.20 to 0.50 pound of fat; the average is 0.33 pound. As we have stated previously, the amount of fat lost in cheese-making is practically independent of the amount of fat in the milk used. When a cheese-maker says that he cannot make cheese from normal milk containing over 3.5 or 4 per cent. of fat without having extra large losses of fat in whey, he classes himself as an incompetent workman.

Why is it necessary to lose any milk-fat in cheese-making? We have seen that fat is present in milk in the form of very small balls or globules, distributed through the milk in enormous numbers. Now, when rennet coagulates or solidifies the milk casein throughout the mass of milk, the fat-globules are retained or imprisoned

in the solidified mass just where they happen to be at the instant. coagulation takes place. When the curd knife passes through the solid mass, large numbers of fat-globules are exposed on every cut surface, and many of these fall into the whey and so are not retained in the cheese.

What conditions contribute to loss of milk-fat in cheese-making? In abnormal milk, when the casein is small in amount in proportion to fat or when it fails to coagulate normally, there are extra losses of fat. Any condition that interferes with complete coagulation by rennet, such as marked dilution of milk by water, presence of preservatives like salt, formalin, etc., is likely to increase loss of fat. Jarring or stirring the milk after coagulation has commenced and before it is completed results in increased loss of fat. Other conditions causing abnormal losses of fat are cutting the curd when it is too soft or cutting it too fine; violent, careless and rapid motions of knife in cutting curd; heating curd too rapidly or too high; piling curd too much; putting curd to press too warm; too rapid application of pressure in cheese hoop. Fermentations producing floating curd, excessive acidity of milk and forms of fermentation that dissolve casein also contribute to losses of fat in cheese-making.

(3.) Loss of Milk-Casein in Cheese-Making.—The casein lost in cheese-making is probably lost mostly in the form of fine particles of coagulated paracasein, which pass through the strainer when the whey is removed from the curd. These minute particles can readily be seen by letting a pail of freshly-drawn whey stand until the curd particles settle, and then pouring off the whey, when a noticeable quantity of finely-divided curd can be seen at the bottom of the pail. This passage of curd into whey is not entirely avoidable, but is made needlessly greater by careless or violence in cutting curd and in subsequent handling, by agitation while drawing off the whey and by imperfect strainers. Any condition that interferes with the complete coagulation of milk-casein by rennet causes loss of casein. Some forms of fermentation convert the casein into compounds not acted on by rennet or dissolve the curd after coagulation, and thus cause a loss of 0.10 to 0.15 pound of casein, and this loss appears to be quite independent of the amount of casein in the milk.

68. Relation of Composition of Milk to Composition of Cheese.

It was formerly believed that cheese of the same composition is made from all kinds of milk. On this assumption the partial skimming of milk for cheese-making was defended.

(1.) In Normal Milk.—In the following table, we present some figures showing how the change in composition of milks affects the

composition of the cheese made from those milks, the conditions of manufacture being the same:

Per cent. of fat in milk.	Per cent .of water in cheese.	Per cent. of fat in cheese.	Per cent. of paracasein compounds in cheese.
3	39.4	32.2	23.4
3.25	39.0	32.9	23.1
3.50	38.1	33.9	23.0
3.75	37.5	34.7	22.8
4.00	37.3	35.2	22.5
4.25	37.0	35.7	22.3
4.50	36.5	36.3	22.2

These figures show that in cheese made from poorer milk, the cheese contains in 100 pounds more water and more paracasein and less fat. As the milk grows richer in fat, the fat in the cheese increases in proportion to water and paracasein compounds. Hence, it is very clear that the composition of cheese is dependent upon the composition of milk, provided, of course, the cheese is made in a normal manner, so as to avoid excessive losses of fat.

(2.) In Skim-Milk.—In what respect does cheese made from normal milk differ from that made from milk which has had more or less of its fat removed? First, let us see in what way removal of fat from milk affects the composition of the milk. We will illustrate by taking milk containing 4 per cent. of fat and 2.50 per cent. of casein, and remove from the milk varying amounts of fat. The results are indicated in the following table. We assume here that we simply remove fat without any other constituents:

	Pounds of fat removed from 100 pounds of milk.	Pounds of fat left in 100 pounds of milk.	Pounds of casein in milk.	Pounds of casein for one pound of fat.
Normal milk,	0	4.00	2.50	0.63
Skim-milk,	0.50	3.50	2.50	0.71
Skim-milk,	1.00	3.00	2.50	0.83
Skim-milk,	1.50	2.50	2.50	1.00
Skim-milk,	2.00	2.00	2.50	1.25
Skim-milk,	2.50	1.50	2.50	1.67
Skim-milk,	3.00	1.00	2.50	2.50
Skim-milk,	3.50	0.50	2.50	5.00
Skim-milk,	4.00	0	2.50	.....

With additional removal of fat from milk, the fat in milk decreases constantly, while we represent the casein that remains as being the same, though in actual practice it would increase a little. While

in the normal milk the casein is very much below the fat in quantity, the casein gradually becomes nearer in amount to the fat until they are equal, after which further removal of fat steadily reduces the amount of fat below that of casein. These changed relations are shown in the last column. In normal milk, there is for one pound of fat less than two-thirds of a pound of casein. When 1.5 pounds of fat have been removed from the milk, the amounts of fat and casein in the resulting skim-milk are just equal, or as one to one. After taking out 3 pounds of fat from 100 pounds of milk, we have left in the resulting skim-milk two and one-half times as much casein as fat, and, with the removal of 3.5 pounds of fat, the remaining skim-milk contains five times as much casein as fat. We have already seen above what effect this has on the composition of cheese made from such milk. The casein and water rapidly increase in the cheese, while the fat decreases. The tabulated figures below give the practical composition of cheese made from some of the milks represented in preceding table:

	Pounds of fat removed from 100 pounds of milk.	Pounds of fat in 100 pounds of milk.	Per cent. of fat in cheese.	Per cent. of water in cheese.	Per cent. of paracasein compounds in cheese.
Normal milk and cheese,	0	4.00	37.3	35.2	22.5
Skim-milk and cheese, ...	1.00	3.00	31.4	37.4	26.2
Skim-milk and cheese, ...	2.50	1.50	19.0	44.4	31.6
Skim-milk and cheese, ...	3.50	0.50	7.3	50.7	37.0

(3.) In Milk Containing Added Cream.—The addition of cream to normal milk has, both upon the milk and the cheese made from it, an effect contrary to that produced by removing fat from milk. The greater the amount of cream added to normal milk, the greater will be the proportion of fat, both in the milk and in the cheese made from it, and the less in proportion will be the casein and water in both the milk and the cheese.

69. Composition of Milk in Relation to Quality of Cheese.

It has been well established that the relation of fat to casein in milk governs, to some extent, the commercial quality of the cheese, other conditions being the same. How closely dependent quality of cheese is upon the relation of fat to casein in milk we cannot say in all cases. Starting with extremes, we know that the character of skim-milk cheese, which is mainly casein and water and

salt, is very different from that of whole-milk cheese. Skim-milk cheese is usually lacking in fine cheese flavor and is more often "off" in flavor, and usually contains abnormally large proportions of water. It acquires bad flavors easily. It is usually imperfect in texture and "corky" in body. We also know that cheese made from milk containing added cream is superior in flavor and other palatable qualities to that made from normal milk. As a rule, cheese made from the milk of Jersey or Guernsey cows is superior to that made from the milk of Holstein cows. In general, the greater the proportion of fat to casein in milk the better is the quality of the cheese made from such milk.

70. Standard of Composition for Whole-Milk Cheese.

How can we distinguish whole-milk cheese, commonly called "full creams," from cheese made from partially skimmed milk? As a rule, cheese made from normal milk will rarely be found to contain less than 32 per cent. of fat, even in the green cheese, and, of course, much less likely to when it comes into market after losing considerable moisture. Cheese made from normal milk would be apt to contain less than 32 per cent. of fat only in case of some abnormal conditions of manufacture, by which the cheese was made to contain an excessive amount of moisture or lose an excessive amount of fat in the process of making.

Then, again, if we take the solids of the cheese as a basis for a standard, we find that rarely, if ever, does cheese made from normal milk have its solids consist of less than 50 per cent. of fat. Taking the solids of average cheese, leaving the water out of consideration, we have in 100 pounds of cheese 35.2 pounds of fat, 22.5 pounds of paracasein compounds, and about 5 pounds of salt, ash, etc., making a total of 62.7 pounds of solids in 100 pounds of cheese, the rest being water. Now, of the 62.7 pounds of solids in 100 pounds of cheese, 35.2 pounds are fat, and this amount is 56 per cent. of the total solids. In this case the fat would have to drop below 31.5 per cent. in the cheese in order to be 50 per cent. of the total solids of the cheese.

71. Methods of Paying for Milk for Cheese-Making.

Until ten years ago or less, the universal custom prevailed of paying for milk at cheese factories by weight alone. This method was based upon the erroneous supposition that, for the purpose of making cheese, milk is milk, and that all kinds of milk are of equal value for cheese-making. The data presented in the preceding pages show by overwhelming evidence that these suppositions

are false. We know that milk varies greatly in its composition and that the cheese-making value of milk varies with its composition.

In paying for milk for cheese-making, absolute fairness can be realized in every individual case only by a careful, direct determination of both fat and casein, the two solid constituents of milk that make cheese, but this is not practicable. However, fat in milk alone can be used as a fair basis in determining the value of milk for cheese-making, for the reasons (1) that the amount of cheese made from different milks is nearly, not exactly, in proportion to the amount of fat present in milk, and (2) that cheese made from milk rich in fat has a higher quality and market value than cheese made from milk poorer in fat.

When milk is paid for by weight alone, each patron receives the same amount of money for 100 pounds of milk, without any regard whatever for the composition of the milk or the amount of cheese it will make. The amount of cheese made from 100 pounds of each kind of milk specified in the table below is the sum of 8.55 pounds and 10.40 pounds, or a total of 18.95 pounds, which, at 10 cents a pound, brings 189.5 cents. This is divided equally between the two patrons, because each furnishes the same amount of milk. Hence, each receives 94.75 cents for the cheese made from his milk.

	Pounds of fat in 100 pounds of milk.	Pounds of cheese made from 100 pounds of milk.	Amount of money received when divided according to yield and composition of cheese, or on fat basis—Cents.	Amount of money received when divided according to weight of milk furnished—Cents.
A,	3	8.55	82.1	94.75
B,	4	10.40	107.4	94.75

When payment is made by the weight-of-milk method, A receives the same amount of money for 8.55 pounds of cheese that B receives for 10.40 pounds; A receives over 11 cents for each pound of the cheese made from his milk, while B receives only 9.1 cents a pound for the cheese made from his milk. A receives 31.6 cents for each pound of his milk-fat, while B receives only 23.7 cents for each pound of his. A receives for 100 pounds of milk 12.65 cents, which belongs entirely to B, because this extra money comes solely from the additional amount of more valuable cheese produced by the milk of B. One method makes no difference in the value of the milk furnished, while there actually exists a difference of 25.3 cents for 100 pounds of milk in favor of B. Estimated for a season, the difference be-

tween the dividends of A and B should be not less than $7.50 for each cow. That gross injustice is inevitably done, when milk is paid for by the weight-of-milk method, must become too obvious to require further discussion.

72. Calculating Dividends on Milk-Fat Basis at Cheese Factories.

In section 46, p. 60, details were given, showing how to calculate dividends at creameries when payment is made on the basis of the milk-fat. The same method applies in all details to the calculation of dividends on the milk-fat basis at cheese factories.

73. Composition of Whey.

Whey varies in composition according to the composition of the milk from which it comes and also according to the conditions of manufacture employed in cheese-making. The following table gives the extremes and average of composition of whey, as found in New York State cheese factories:

	Average.	Highest.	Lowest.
Per cent. of water,	93.04	93.57	92.48
Per cent. of total solids,	6.96	6.43	7.52
Per cent. of fat,	0.36	0.23	0.55
Per cent. of casein,	0.10	0.15	0.05
Per cent. of albumin,	0.72	0.90	0.45
Per cent. of sugar,	4.00	4.50	3.50
Per cent. of lactic acid,	0.20	0.25	0.16

In comparison with skim-milk and buttermilk, we notice in whey a smaller amount of casein and a little more fat. Whey may be used as food for calves and pigs, but is better used when sweet and in connection with other foods. The feeding value of whey has been estimated to be about seven cents per 100 pounds. It is a good plan to sterilize whey in the whey-vat and keep the vat as clean as possible.

74. Composition of Cheese.

We have already studied to some extent the variations found in the composition of cheese and the causes of these variations, as they are related to the composition of milk and conditions of manufacture. In the table following, we will give the average composition of cheese in the green condition and the same when ripened in condition for consumption:

	In green cheese—Per cent.	In ripened cheese—Per cent.
Water,	36.80	31.75
Solids,	63.20	68.25
Fat,	33.75	36.75
Paracasein, etc.,	23.75	25.50
Ash, etc.,	5.70	6.00

75. The Value of Cheese as Food.

There is more or less prejudice against cheese as an article of diet on the ground of its being indigestible. This prejudice has arisen, undoubtedly, because skim-milk cheese and uncured whole-milk cheese are difficult of digestion. Many of our American people want something very mild in flavor and pretty solid in consistency. They find these conditions in cheese partly cured and in well-made skim-milk cheese. For the average stomach, cheese should be cured two months or more, according to the temperature, before it is eaten. People should be taught to eat only well-ripened cheese. The test of the proper ripeness of cheese is that a piece placed on the tongue and held a little while dissolves completely. By curing at low temperatures for longer periods of time, it is easily possible to produce cheese showing this behavior and at the same time having a mild flavor. We will briefly consider some of the strongest claims cheese has as an article of diet.

(1). Cheese is One of Our Most Concentrated Foods.—Taking various common foods, and considering the amount of water and waste portions present in them and the amount of actual food materials contained in them, we can present the following figures:

	Pounds of water and waste material in 100 pounds.	Pounds of actual food material in 100 pounds.
Fresh fish,	90	10
Oysters,	88	12
Chicken,	83	17
Hens' eggs,	76	24
Round beefsteak,	71	29
Potatoes,	67	33
Ribs of beef,	65	35
Tenderloin beefsteak,	60	40
Bread, white,	45	55
Cheese,	33	67

These figures show very clearly that, of our more common foods, cheese is among the most highly concentrated.

(2.) Cheese is One of Our Cheapest Foods.—Taking average market prices and computing the price we pay for actual food materials, excluding water and waste, we have the following figures, as representing the cost of one pound of actual food material in the foods given:

Fresh fish,	$1 30
Oysters,	1 25
Chicken,	82
Eggs,	62
Ribs of beef,	50
Tenderloin beefsteak,	44
Round beefsteak,	42
Cheese,	22

(3.) Cheese furnishes a larger amount of protein than any other ordinary available food excepting canned and dried meats. Protein is an extremely valuable food constituent, furnishing, as it does, material for lean flesh, albuminoids, nitrogenous compounds of the blood, nerve tissues, tendons, skin, hair, etc. No other food element can take the place of protein. Cheese contains about one-fourth of its own weight of protein. The cost of protein in cheese is probably less than in any other food material, speaking of our American cheddar cheese retailing at 15 to 20 cents a pound.

CHAPTER XI.

METHODS OF TESTING MILK AND ITS PRODUCTS.

76. The Need of Tests.

It is necessary to ascertain the amount of some of the constituents of milk and of its products in order that we may be in position to judge the value of the materials in question for one purpose or another. Thus, at creameries, cheese factories and milk stations, it is necessary to determine the amount of fat in each patron's milk, in order to pay for the milk on the basis of the fat content. It is necessary for a dairyman who would be progressive to know the amount of fat in the milk of each individual cow of the herd, in order to know what the value of the cow is to him; because, only by

such knowledge can one obtain the most profitable herd. Frequently, in making butter, it is desirable to know the amount of fat present in cream, also in the case of selling cream. Then, it is necessary, in butter-making, as previously pointed out (see section 28, p. 44) to determine the amount of acid in cream, frequently, also, in selling milk, in order to ascertain the approximate age of milk when it is received by the retailer. Another form of test that dairymen have occasion to make, especially where they purchase milk from other parties, is the estimation of solids in milk to find out if the milk has been adulterated by addition of water or by removal of fat. From these preliminary statements, it can readily be seen how important a part the testing of milk and its products plays in the problems which the dairyman constantly has before him.

77. The Babcock Test.

The Babcock test is a method for determining the amount of fat in milk and its products. It was devised in 1890 by Dr. S. M. Babcock, chief chemist of the Wisconsin Experiment Station. It is probably not too much to say that, in giving to dairymen this simple method of finding out how much fat a sample of milk contains, Dr. Babcock made the greatest contribution to the real progress of dairying ever made by any one man. There are other tests which are, more or less, imitations of the Babcock test, but none that, in all respects, equals it.

In general, this test is based on the action of strong sulphuric acid upon milk-casein, albumin and milk-sugar, by which the milk-fat is released from the influence of these other compounds and thus is free to collect in one separate mass. In order to hasten the complete separation of the fat from the rest of the liquid, centrifugal force is employed.

78. Advantages and Disadvantages of the Babcock Test.

Before describing in detail the method of employing the Babcock test, it is desirable to call attention to the special points of its merits and demerits.

(1.) Advantages.—(a.) The apparatus and materials are inexpensive, both in respect to first cost and also cost of making tests. (b.) The test is accurate enough for all practical purposes, giving the real per cent. of fat within two-tenths of one per cent., comparing most favorably with the most accurate laboratory methods. (c.) The test is quickly made, requiring less than fifteen minutes. (d.) The operation of the test is simple and easy. Only one chemical is used and no chemical training or knowledge is necessary to operate it.

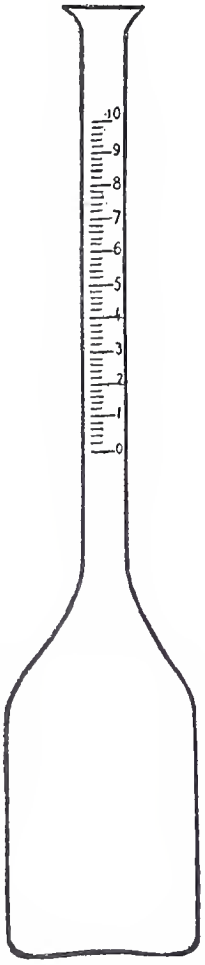

Fig. 8. Milk bottle.

Fig. 9. Pipette.

Fig. 12. Greiner's Pipette.

Fig. 11.

Fig. 10. Acid measure.

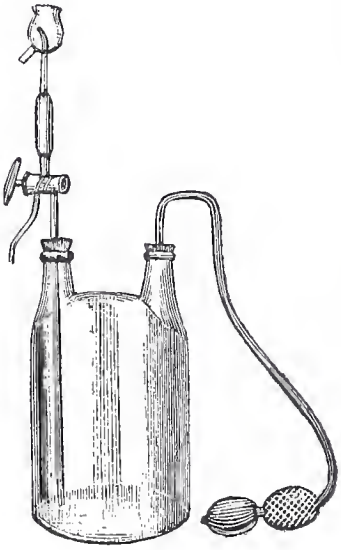

Fig. 13. Acid bottle.

(e.) The percentage of fat in each case is shown directly to the eye without special calculations or reference to tables. (f.) Only a small amount of milk is required to make the test. (g.) The apparatus does not readily get out of order and chances for accidents are absent with properly made machines. (h.) One sample or a large number of samples can be tested at the same time with the same facility. (i.) The results can be easily confirmed by repetition of tests. (j.) Completed tests can be set aside and will keep for future reference for a long time, if desired. (k.) The accuracy of the apparatus employed can be easily ascertained. (l.) Sour milk can be correctly tested, provided it can be correctly sampled. (m.) The test can, with some little modifications, be used in determining the amount of fat in cream, skim-milk, buttermilk, whey, condensed milk and cheese. (n.) The test is applicable to all kinds of milk of which good samples can be obtained, without regard to breed or other conditions.

(2.) Disadvantages.—(a.) Sulphuric acid, which is used in the test, is a dangerous substance, if handled carelessly. Therefore, its use requires constant attention and caution. (b.) The strength of the acid must be uniform and so must be examined from time to time. (c.) The speed of the centrifugal machine used must be properly regulated in order to secure correct results. (d.) The temperature of the milk at the beginning and end of the test must be controlled. (e.) The graduated glassware is sometimes incorrect. (f.) Attention must be carefully given to every detail of the operation, if correct results are to be obtained. These disadvantages, it will readily be seen, are all easily overcome. They are all practically summed up in the one requirement that careful attention must be given to all details. Any person who cannot be careful should not try to use the Babcock test in responsible work, much less should he try to use any other; in fact, such a person has no place in a creamery or cheese factory or in any dairy operations.

79. Description of Apparatus and Materials Used in Making Babcock Test.

(1.) Test Bottles.—The form of bottle used in this test is shown in Fig. 8. The neck is so graduated that each division represents two-tenths of one per cent. and five of the divisions represent one per cent. when 17.5 cubic centimeters or 18 grams of milk are used in the test. The graduation extends from 0 to 10 per cent., a range sufficient for all ordinary work with milk. When cheese or cream is tested for fat, a bottle like that shown in Fig. 18 or 19 is used. When skim-milk, buttermilk or whey is to be tested, bottles like that shown in Fig. 20 or 21 should be used according to directions given hereafter.

The divisions on the neck of the bottles should be uniform and the lines run straight across the neck, and not obliquely. When the numbers or lines become indistinct from having the blackened portions washed off, they can be restored by rubbing over the scale with a lead pencil or with a cloth having a little black paint on it. Each bottle should be numbered. A convenient way is to have the number stamped on a copper ring and slip this over the neck of the bottle.

The accuracy of the scale on the neck of the bottle can be approximately tested as follows: Fill the bottle to the mark with water, wipe out the neck of the bottle with a piece of filter or blotting paper and then measure into the bottle 2 c. c. of water with an accurate pipette; this should fill the bottle to the 10 per cent. mark. If bottles vary more than 0.2 per cent. in the whole length of the scale from 0 to 10 per cent., they should not be used.

(2.) Pipette for Measuring Milk.—A pipette like that shown in Fig. 9 is the form commonly used. This should hold 17.6 c. c. when filled to the mark. This will deliver about 17.5 c. c. of milk or 18 grams. It is important that the pipette should be accurate and should hold exactly the amount stated above. Other forms of pipette for measuring either milk or acid are shown in Figs. 11 and 12.

(3.) Measure for Acid.—A cylinder of glass like that shown in Fig. 10, with a lip to pour from and a single mark at 17.5 c. c. is the form commonly used. It is not necessary that this measure should be completely accurate, since the amount of acid used can be varied a little without affecting the test. In Figs. 13 and 14 are shown automatic pipettes which may be used to advantage where a large number of tests is made daily. This apparatus saves much time but has the disadvantage of being somewhat expensive and readily broken unless carefully handled. The automatic pipettes shown in Figs. 11 and 12 will probably be found to be the most convenient for the majority of those who use the test.

(4.) Centrifugal Machine.—Various forms of centrifugal machines have been devised for this work (see Figs. 15, 16 and 17). A wheel less than twelve inches in diameter should not be used and it need not exceed twenty inches. A wheel measuring twelve inches in diameter should be made to revolve 1,200 times per minute, while, for those of larger diameter, a smaller number of revolutions will suffice, but not less than 700 revolutions per minute should be used for the larger ones. It is better to use a machine in which the motion is transmitted by cog wheels, since, when the motion is transmitted by belt or friction, there is danger of slipping; and the result is much less motion than is intended and an imperfect separation

Fig. 14.

Fig. 15. Small-sized tester.

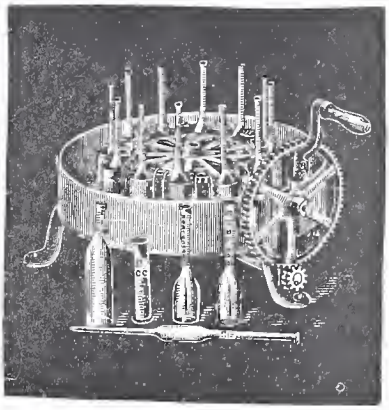

Fig. 16. Hand tester.

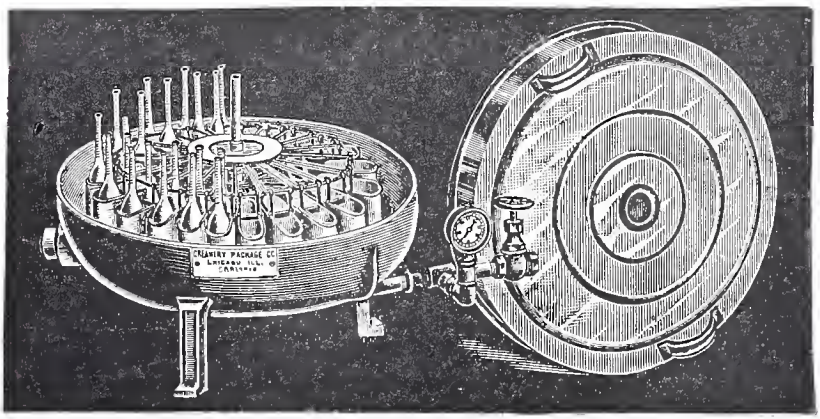

Fig. 17. Turbine steam tester.

of fat. Machines which carry an even number of bottles are to be preferred. The best form of machine for use in factories is a steam turbine machine. They have the advantage of maintaining an even speed, they keep the bottles hot and supply distilled water for filling.

(5.) Commercial Sulphuric Acid (Oil of Vitriol).—This should have a specific gravity of 1.82 to 1.83. If the acid is much stronger, the fat will be dark in color and its amount hard to read. If the acid is weaker than 1.82, there is liability of some casein remaining undissolved and this will mingle with the fat and make the test unsatisfactory. If the acid is too strong, good results may be secured by using less. It is best to purchase acid at 1.82 or a trifle above and not attempt to dilute the strong acid. Dairy-supply houses should keep acids of the right strength made up in carboys for the trade. The acid should be kept in tightly stoppered bottles, because, if exposed to air, it rapidly absorbs moisture and becomes too weak. The stopper should be of either glass or rubber and, in no case should a common cork be used, since it would be quickly destroyed by the acid. Sulphuric acid is extremely corrosive and is dangerous to handle except with care. It quickly ruins clothing or leather on which it falls and seriously burns the skin if left in contact with the acid for a few minutes. If sulphuric acid gets upon the skin anywhere, it should be immediately and thoroughly washed with abundance of water. Too great care can not be exercised in handling this acid.

80. How to Sample Milk for Testing.

(1.) Conditions Making Sampling Difficult.—Milk that has soured and thickened or in which cream has risen and dried, so as to form a clot or skin, is difficult to sample properly and will generally be found to give low results. The same is true of milk in which the fat has been partially churned and formed into little butter granules that rise quickly to the surface. Such churning is liable to occur in milk that is transported long distances in vessels that are not full. However, these difficulties are seldom met in milk that has received careful attention in its preliminary handling.

(2.) How to Take a Sample of Milk for Testing.—The sample to be tested is thoroughly mixed by pouring the milk from one vessel to another two or more times, thus making every part of the milk contain the same amount of fat. If the pipette is not dry, when used, it should be filled with the milk to be tested and then thrown away before taking the sample for testing. The measuring pipette (see Fig. 9), is at once filled with milk after the mixing by sucking up the milk into it, until it reaches above the mark on the stem of the pipette. Then the forefinger, which must be dry, is quickly

placed over the upper end of the pipette before the milk runs down below the mark. A little practice will be required to do this. By lightening the pressure of the finger on the end of the pipette, the milk is allowed to flow out until it just reaches the mark on the stem. If the pipette is correctly made, the quantity of milk in the pipette is just 17.6 cubic centimeters.

81. Running Milk Sample into Test Bottle.

Having the pipette containing just 17.6 c. c. of milk, we now hold the pipette obliquely, placing its point in the neck of the test bottle and the milk is allowed slowly to flow down the inside of the neck. Not a drop of milk should be lost in this operation. The portion of milk remaining in the point of the pipette is removed by blowing through the pipette before removing it from the test bottle. The pipette should never be held perpendicularly straight over the test bottle, running the milk straight down in, since the neck may choke up with milk and run over the top.

82. Adding Acid to Milk in Test Bottle.

(1.) Strength of Sulphuric Acid for Test.—The sulphuric acid to be used in the Babcock test must have a strength corresponding to a specific gravity not below 1.82 or above 1.83. If the acid is stronger, the fat in the final part of the test will be dark in color and its amount hard to read. If the acid is weaker than 1.82, there is danger of some casein remaining undissolved and this will mingle with the fat and make the test unsatisfactory. It is possible to secure good results with strong acid by using somewhat less, but it is best to purchase acid of just the right strength. The sulphuric acid should be kept in bottles tightly stoppered with glass stoppers, because it rapidly absorbs moisture and becomes too weak in time if exposed to the air.

(2.) Caution in Handling Acid.—If, in handling, sulphuric acid gets on the skin anywhere it should be immediately and thoroughly washed with abundance of water. Too great care cannot be exercised in handling this acid.

(3.) Measuring Acid and Adding to Milk.—When one has the samples of milk ready in the test bottles, then the acid measure is filled to the 17.5 c. c. mark, and from this is poured into the test bottles. The acid being much heavier than the milk sinks to the bottom of the bottle without mixing, the milk floating on top. Much care should be exercised in pouring the acid into the test bottle containing the milk. This is best done by holding the bottle in an inclined position, so that the acid will follow the inside walls down

to the bottom of the test bottle and not drop through the milk in the center of the bottle; and, moreover, unless this is done, the neck is liable to choke up and cause the acid to overflow on one's hands. Failure to observe this precaution will generally cause blackening of the fat. The pouring should be slow and steady. It is well, also, while pouring in the acid, to turn the test bottle around slowly so that the acid may successively come in contact with the different portions of the inside walls of the neck and wash down any milk adhering. Unless this is done, some milk may remain in the neck, in which case its casein will be precipitated and not redissolved and thus the fat will contain particles of casein.

(4.) Mixing Milk in Test Bottle.—As soon as the acid has been measured into the test bottle, the acid and milk should be thoroughly mixed. This is best done by giving the bottle a rotary motion, with gentle shaking. Much motion up and down should be avoided, since milk may be thrown up into the neck beyond the reach of the acid and undissolved casein resulting from this will mix with the fat; and ,then, violent motion up and down might throw some of the acid out upon one's hands or clothing. When the acid and milk first mix, the casein is precipitated in a more or less solid mass, which gradually redissolves. The mixing once begun should continue until one has made certain that the casein is entirely redissolved. The chemical action of the acid upon the compounds of the milk produces much heat and, as stated above, the solution, at first yellow, changes gradually through varying shades of yellow and brown to a dark-brown color, provided the acid is not too strong. This color is due mainly to the charring or partial burning of the milk-sugar by the acid. Samples of milk that have been preserved for some time with potassium bichromate or formalin require rather more time and agitation for redissolving the casein than do samples of fresh milk.

83. Whirling Test Bottles.

(1.) Whirling the Bottles.—The test bottles containing the mixture of milk and acid should be placed in the machine and whirled directly after the acid is added. An even number of bottles should be whirled at the same time, and they should be placed in the wheel in pairs opposite to each other, so that the equilibrium of the apparatus will not be disturbed. When all of the test bottles are placed in the apparatus, the cover is placed upon the jacket, and the machine turned at the proper speed, 600 to 1,200 revolutions per minute, according to diameter of tester, for about five minutes. The test should never be made without the cover being placed upon the jacket, as this not only prevents the cooling of the

bottles when they are whirled, but in case of the breakage of bottles may protect the face and eyes of the operator from injury by pieces of glass or hot acid. The machine should be frequently examined to make certain that there is no slipping of belts or frictional bearings which may cause too slow motion and result in an imperfect separation of the fat. Managed in this way no extra heat is required, as that caused by the chemical action is sufficient to keep the fat liquid. If the bottles have stood, after the acid is added, until the contents are cooled below 100 degrees F., they should be warmed to about 200 degrees F. by placing them in hot water before whirling.

(2.) Filling the Bottles with Hot Water.—As soon as the bottles have been sufficiently whirled, they should be filled only to the neck with hot water. If practical, distilled or rain water should be used for the purpose. The bottles are most conveniently filled by placing a vessel containing boiling water above the machine, and by means of a syphon made from a small rubber tube with a glass tip, run the water directly into the bottles without removing them from the wheel. The flow of water can be perfectly controlled by a pinch-cock upon the rubber tube. If only a few tests are to be made, the bottles may be easily filled with a pipette, or by pouring from a graduate. The cover should then be replaced and the machine turned for about one minute, after which the neck of each test bottle is filled with hot water to the upper limit of the scale or nearly so, and the whirling is then repeated for another minute. Unless the hot water is added in two portions, the fat is often apt to be mixed with particles of various impurities, which render the reading uncertain.

84. Measuring Amount of Fat.

After the last whirling is completed, the test bottles are removed from the machine and placed in water which has a temperature between 140 degrees and 150 degrees F. The per cent. of fat is read at this temperature. To measure the fat, hold the test bottle upright, having the graduated scale on a level with the eye; notice the divisions which mark the highest and lowest limits of the fat. The difference between gives the per cent. of fat directly. The reading can easily be taken to half divisions or to one-tenth of one per cent.

The line of division between the fat and the liquid beneath is nearly a straight line and no doubt need arise concerning the reading at this point, but, the upper surface of the fat being concave, errors often occur by reading from the wrong place. The reading should be taken at the line where the upper surface of

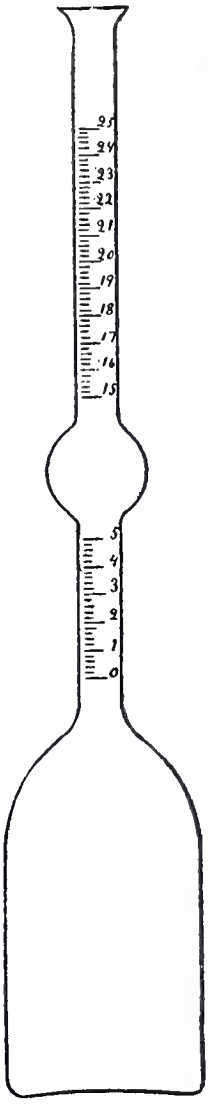

Fig. 18.

Fig. 19.

Cream bottles.

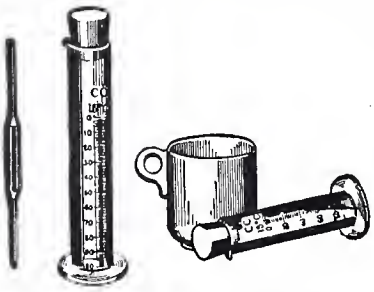

Fig. 24. Farrington's test.

Fig. 20.

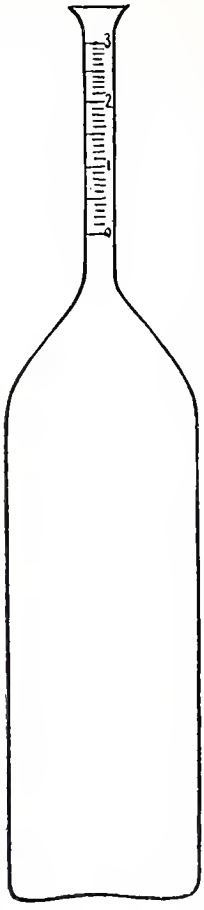

Fig. 21.

Bottles for skim-milk, whey, etc.

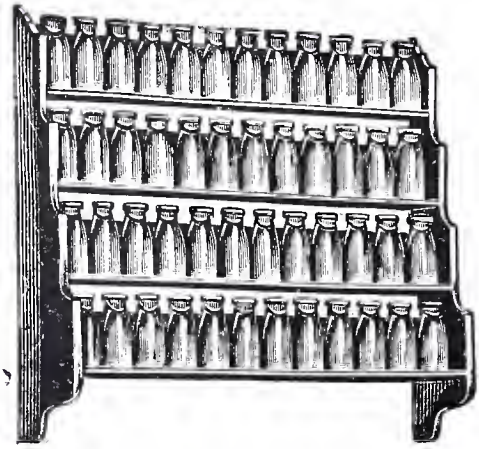

Fig. 22. Composite test sample rack.

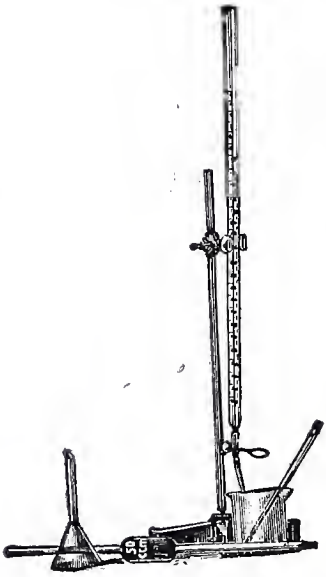

Fig. 23. Mann's

the fat meets the side of the tube and not from the surface of fat in the center of the tube nor from the bottom of the dark line caused by the refraction of the curved surface.

The reading may be made with less liability of error by measuring the length of the column of fat with a pair of dividers one point of which is placed at the bottom and the other at the upper limit of the fat. The dividers are then removed and one point being placed at the o mark of the scale on the bottle used, the other will be at the per cent. of fat in the milk examined.

Sometimes bubbles of air collect at the upper surface of the column of fat and prevent a close reading; in such cases a few drops of strong alcohol (over 90 per cent.) put into the tube on top of the column of fat, will cause the bubbles to disappear and give a sharp line between the fat and alcohol for the reading. Whenever alcohol is used for this purpose ,the reading should be taken directly after the alcohol is added, as after it has stood for a time the alcohol partially unites with the fat and increases its volume.

Whenever the fat is not quite clear, more satisfactory results may be obtained by allowing the bottles to stand until the fat has crystallized, and then warm them by placing the bottles in hot water, before taking the reading.

If the column of fat is less than about one division, as will often happen with skim-milk and buttermilk, it may assume a globular form instead of a uniform layer across the tube; when this occurs the fat can usually be estimated with sufficient accuracy by simple inspection, but in such cases it is better to use specially constructed bottles, like those illustrated in Figs. 20 and 21.

85. Testing Cream by Babcock Test.

Accurate results can be obtained by the Babcock test in ascertaining the amount of fat in cream, but much greater care has to be taken in sampling cream. Cream that is sour, or that has been exposed to air until the surface has dried, cannot be accurately sampled. The same is true of centrifugal cream that is badly frothed. Sweet cream, from Cooley cans, that is not too thick to flow readily from the pipette may be tested with satisfactory results. The process, however, must be modified slightly from that used with milk, as the amount of fat in cream is so large that it cannot be measured in the ordinary test bottle, if the usual quantity is taken for the test, besides a much greater error results from the cream which adheres to the pipette than with milk. Both of these difficulties may be overcome by taking two or three test bottles and dividing the test sample between them into as nearly equal portions as can be judged by the eye. The pipette is then filled with

water and this is run into the tubes in the same way as the cream. If three bottles are taken the pipette is filled with water a second time and emptied into the bottles as before. This serves to rinse the cream from the pipette, and at the same time to dilute it to a point where it can be tested in the same way as milk. The bottles are then treated in the usual manner, and the reading of the tubes added together for the per cent. of fat in the cream. The necessity of dividing the sample of cream as directed above may be avoided by the use of the special test bottle shown in Figs. 18 and 19. Cream may also be tested in the ordinary bottles by diluting it with three times its volume of water and proceeding in exactly the same manner as with milk, the reading being multiplied by three.

Owing to the low specific gravity of cream, the test sample, if of the same volume, will weigh less than that of milk, and consequently the per cent. of fat as shown by the scale will be less than is found by gravimetric analysis, in proportion as the weight is less than 18 grms. Where a delicate balance is available, this error may be entirely avoided by weighing the cream used in a test, and calculating the per cent. of fat by multiplying the scale reading by 18, and dividing the product by the weight in grams of cream taken.

If 17.6 c. c. of cream are taken and the portion adhering to the pipette is rinsed into the test bottle, a close approximation of the true result may be obtained without weighing by correcting the scale reading as follows: For a scale-reading of 20 per cent., add 0.25 per cent.; for a scale-reading of 15 per cent., add 0.1 per per cent. Readings between these may be corrected in proportion. Below 10 per cent. no correction is necessary.

Cream may be tested in the ordinary bottles in the manner proposed by Mr. Winton, in Bulletin 108, of the Connecticut Experiment Station, by using a pipette having a capacity of 6.04 c. c., which will deliver about 6 grams of average cream or one third of the weight of the usual sample. When this pipette is used, about 12 c. c. of water should be added to the cream in the bottle before adding the acid. The usual amount of acid should be taken and the test completed in exactly the same way as with milk. The reading should be multiplied by three to obtain the per cent. of fat in the cream. No correction for the specific gravity is necessary when this pipette is used.

86. Testing Skim-Milk, Buttermilk and Whey.

With all products like the above, which usually contain less than one per cent. of fat, more accurate results are obtained by the

use of a special test bottle like that in Fig. 20 or 21. Less acid is required for whey than milk.

If only traces of fat appear in the neck of the bottle, the fat in the milk examined may be nearly 0.1 per cent. and this reading will be more nearly correct than estimates of from .01 to .05 per cent., which often appear in the agricultural papers. The reason for this is that minute quantities of fat are either dissolved or not separated by the method. The amount of fat lost in this way is about the same for all milks; it is compensated for when sufficient fat is present to form a complete layer across the neck of the bottle by reading to the point where the fat meets the glass instead of at the concave surface.

87. Testing Condensed Milk.

The estimation of fat in condensed milk is accomplished in exactly the same way as with cream. As a rule, condensed milks are so thick that it is impractical to measure the test sample directly with a pipette. This difficulty may be overcome by carefully diluting the milk with a known volume of water, making the analysis of this and correcting the result for the quantity of water added. The best method is to weigh the sample into a test bottle, taking about 8 grams, and after adding about 10 c. c. of water, completing the test in the same manner as with milk, the per cent. of fat being obtained by multiplying the reading by 18 and dividing the product by the weight, in grams, of the substance taken. The results are satisfactory.

88. Testing Cheese.

The examination of cheese is not as satisfactory as that of other dairy products. The chief reason for this is the unequal distribution of moisture and fat in the cheese, making it very difficult to obtain representative samples. On account of this, tests made from different parts of the same cheese, especially if it be very rich, often vary as much as two or three per cent. in the amount of fat found. To avoid this as much as possible, samples should be taken in a uniform manner.

Where the cheese can be cut, a narrow wedge reaching from the edge to the center of the cheese, will more nearly represent the average composition of the cheese than any other sample. This may be chopped quite fine, with care to avoid evaporation of water, and the portion for analysis taken from the mixed mass. When the sample is taken with a cheese trier, a plug taken perpendicular to the surface, one-third of the distance from the edge to the center of the cheese should more nearly represent the average composition than any other. The plug should either reach entirely through

or only half through the cheese. For inspection purposes, the rind may be rejected but for investigations ,where the absolute quantity of fat in the cheese is required, the rind should be included in the sample. It is well, when admissible, to take two or three plugs on different sides of the cheese and, after splitting them lengthwise with a sharp knife, take portions of each for the test.

For the estimation of fat in cheese, about 5 grams should be carefully weighed and transferred as completely as possible to a test bottle. From 12 to 15 c. c. of hot water are then added and the bottle shaken at intervals, keeping it warm, until the cheese has become softened ,and converted into a creamy emulsion. This may be greatly facilitated by the addition of a few drops of strong ammonia to the contents of the bottle. After the contents of the bottles have become cold the usual amount of acid should be added and the bottles shaken until the lumps of cheese have entirely dissolved. The bottles are then placed in the machine and whirled, the test being completed in the same manner as with milk. To obtain the per cent. of fat, the reading should be multiplied by 18 and divided by the weight, in grams, of cheese taken.

89. Testing Composite Samples at Creameries and Cheese Factories.

Provide a pint or quart fruit-jar for each patron, on which shall be a name or number distinguishing each. In each jar place about as much powdered potassium bichromate as can be held in the empty shell of a 32-oz. cartridge or about as much as one can place on a silver dime; this will keep the milk from souring. Provide a small tin cylinder holding one or two ounces of milk when filled to the brim, provided with a handle of convenient length. When a patron delivers his milk, pour it into the weighing can from a height sufficient to secure thorough mixing of the whole, and immediately, before weighing, insert the small tin cylinder, fill with milk to the brim and transfer to the fruit jar set aside for that patron's milk. In case this pouring does not mix the milk thoroughly ,then stir the milk in the weighing can with a long-handled dipper. This is repeated each day for six or seven days with the milk of each patron. Whenever a fresh sample of milk is placed in the jar, it should be mixed with the milk already in the jar by giving the jar a rotary motion. If this is not done, the cream which separates is liable to adhere tenaciously to the sides of the jar and make it difficult to take an accurate sample when the test is made. Whenever an additional sample of milk is put into a jar, it should be immediately and tightly closed. The jars should be kept in a cool place during the week. If kept too warm, the cream becomes hard and cannot readily be mixed back into the milk, which will cause low results in the test.

The quantity of potassium bichromate suggested above should be enough to keep the milk sweet for a week. In case one finds at any time that the amount does not prevent souring, then one should use more.

If milk is delivered that has firm clots of cream in it, then mix the sample in the weigh can with a dipper and take out a small portion which can be poured from one vessel to another until the clots disappear, after which take out a tin cylinder full and transfer to fruit-jar.

At the end of a week, one has in each fruit-jar a sample of milk which represents the milk delivered during that week. By testing this one sample, one secures the same results he would secure by testing the milk every day. This kind of a sample is known as a "composite sample."

90. Testing Acidity of Milk and Cream.

(1.) General Principles upon Which Acid Testing is Based.—The method of testing acidity in milk or cream is based upon the chemical action taking place between acids and alkalies. For example, if to any acid we add an alkali we change the acid and alkali both into a third compound, each of the others disappearing as acid or as alkali. Thus, suppose to some lactic acid we add some solution of caustic soda in just the right proportion, we then have neither lactic acid nor caustic soda, but a new compound formed by the union of lactic acid and sodium. To find out when a substance is acid or alkaline or neutral, that is, neither acid nor alkaline, we use some third substance, which is called an indicator. One very useful substance to use as an indicator is a chemical compound called *phenolphthalein*. When this substance is added to an alkaline solution, it turns pink, while, in an acid or neutral solution, it is colorless. For use 10 grams of phenolphthalein are dissolved in 300 c. c. of 90 per cent. alcohol, and a few drops of this are used. Now, what use can be made of these facts in ascertaining the amount of acid in milk or cream? We will illustrate: To a measured amount of cream we add some phenolphthalein as indicator, and then to this cream add some caustic soda solution, so prepared that we know just how much caustic soda it contains. We add the caustic soda, stirring the cream after each addition, until finally a pink color appears and does not go away on continued stirring. The appearance of the pink color means that enough caustic soda has been added to combine with all the lactic acid in the cream. Now, we know just how much caustic soda was required to equal the acid in the cream and from this we know the amount of acid in the cream. For dairy work, the caustic soda is prepared in

such a way that a certain amount of it equals one per cent. of lactic acid. The two common forms of acid test are those devised by Mann and by Farrington.

(2.) Mann's Acid Test.—Measure exactly 50 cubic centimeters of the cream or milk into a clean porcelain cup or a glass. Add a few drops of phenolphthalein and then let in some of the "neutralizer" (Mann's name for the alkaline solution), from a burette, previously filled to the zero point. A pink color appears, but disappears on stirring. Continue to add the alkali carefully, stirring the cream or milk all the while. It will be noticed, sooner or later, that the pink color disappears more slowly after each addition of alkali. Finally, a point is reached when the pink color does not disappear even after considerable stirring. Add no more alkali. Then look at the burette and see how many cubic centimeters of alkali have been used. Suppose 30 cubic centimeters of alkali have been required to use up or equal the lactic acid in the cream, then multiply 30 by .018 and the result is 0.54, which is the per cent. of lactic acid in the cream or milk used. (See Fig. 23.)

(3.) Farrington's Alkaline Tablet Test.—In this case, the alkali and phenolphthalein are mixed together in the form of solid tablets. In using this method, one first puts five tablets into a graduated 100 cubic centimeter cylinder and fills this up with water to the 97 c. c. mark with clean soft water, distilled water if possible. The cylinder is then tightly corked and laid on its side until the tablets dissolve. The cylinder must be kept tightly corked, so that none of the solution can be lost while the tablets are dissolving. The solution will be good to use for twenty-four hours after being prepared. Solutions more than a day old should, therefore, not be used. The solid tablets will not change if kept dry. (See Fig. 24.)

In making the test, the cream or milk to be tested is thoroughly mixed and then measured into a porcelain cup with a 17.6 c. c. pipette. This pipette is rinsed once with water, and the rinsings are added to the cream in the cup. Then a few c. c. of the tablet solution prepared as above directed are poured from the cylinder into the cream and thoroughly mixed with it. The tablet solution is added in small quantities until the pink color in the cream or milk lasts for some time. Now, look at the cylinder and see how many c. c. of solution have been used. One c. c. of tablet solution stands for .01 per cent. of lactic acid. Thus, if 20 c. c. of solution are used, there is .20 per cent. of lactic acid; if 50 c. c. are used, the lactic acid is .50 per cent.

91. The Use of Lactometers in Testing Milk.

(1.) The Specific Gravity of Milk.—By the specific gravity of milk, we mean the weight of a given bulk of milk as compared with the weight of an equal bulk of water at the same temperature. For illustration, suppose we have a vat which, when just full of water, contains exactly 1,000 pounds of water. Now, if we fill such a vat full of milk, this amount of milk will weigh about 1,032 pounds, because the milk contains beside the water in it several solid substances heavier than water. Hence, we say the specific gravity of average milk is 1.032. Since the specific gravity of milk depends upon the amount of these solids in it heavier than water, then specific gravity will be found to vary, because we know that the amount of solids in milk varies considerably. So, we find some milk with specific gravity below 1.030, while that of other milk is above 1.035. The casein, albumin and milk-sugar are heavier than water. Since milk-fat is lighter than water, the more milk-fat we have in milk in proportion to the other solids, the lower is its specific gravity. By adding cream to milk, we make its specific gravity less than that of normal milk; on the other hand, by removing fat from milk, we increase the specific gravity, because we remove what it lighter and leave what is heavier than water. The addition of water to normal milk lowers the specific gravity. Thus, it is easily possible by removing cream from normal milk to increase the specific gravity and then, by adding water in right amounts lower the specific gravity back to that of the normal milk. The addition of sugar or salt to milk increases its specific gravity. Since water used to be the most common adulterant of milk, it was thought that adulteration could readily be detected by ascertaining the specific gravity.

(2.) Quevenne Lactometer.—A lactometer is an instrument used for measuring the specific gravity of milk. The Quevenne lactometer has a scale divided into 25 equal parts, going from 15 to 40. Each division is called a degree. These divisions correspond to those on an ordinary hydrometer, ranging from 1.015 to 1.040. The Quevenne lactometer is graduated so as to give correct readings at 60 degrees F. For other temperatures the reading must be corrected by adding .1 for each degree above 60 degrees F., or by substracting .1 for each degree below 60 degrees F. So, when, this lactometer is used, the milk should be at 60 degrees F., or else the correction must be made. If the

Fig. 25. Quevenne's lactometer and thermometer combined.

Quevenne lactometer settles in milk at 60 degrees F. to the point marked 29, it means that the specific gravity is 1.029, the lowest limit allowed for normal milk. (See Fig. 25.)

(3.) Board of Health Lactometer.—Many city milk inspectors in the eastern and middle States used the so-called New York Board of Health lactometer. This does not give the specific gravity of milk directly, as does the Quevenne lactometer, but the scale is divided into 120 equal parts, the mark 100 being placed at the point to which the lactometer sinks when lowered into milk having a specific gravity of 1.029 (at 60 degrees F.), this being taken as the lowest limit of specific gravity in the case of normal milk of cows. The zero mark on the scale shows the point to which the lactometer will sink in water. The distance between these two points is divided into 100 equal parts and the scale is continued below the mark to 120; 100 degrees on the Board of Health lactometer corresponds to 29 degrees on the Quevenne lactometer, and the zero mark for both is 1, the specific gravity of water; hence, we can change the degrees on the Board of Health lactometer into degrees of the Quevenne lactometer by multiplying the readings of the Board of Health lactometer by .29. Tables are often given showing the equivalents.

(4.) Value of Lactometer in Detecting Adulterated Milk.—The value of the lactometer in detecting adulterated milk was formerly greatly overestimated. Taken by itself, the lactometer is thoroughly unreliable and misleading. Its proper use in milk inspection is simply to indicate whether a sample is suspicious and ought to be further investigated by detailed chemical analysis. As pointed out above, a milk could be both skimmed and watered and yet the lactometer would show it to be entirely normal.

(5.) Use of Lactometer in Estimating Solids of Milk.—By finding out the specific gravity and per cent. of fat in milk, it is possible, by making a few calculations, to ascertain quite closely the amount of total solids in milk and the solids-not-fat. Babcock has given useful rules for this purpose, which are as follows:

Rule 1. To find the per cent. of solids-not-fat in milk, add two-tenths of the per cent. of fat to one-fourth of the lactometer reading.

Rule 2. To find the per cent. of total solids in milk, add one and two-tenths times the per cent. of fat to one-fourth of the lactometer reading.

These rules give good results when applied to lactometer readings between 26 and 36 and to milk containing 2 to 6 per cent. of fat.

Example 1. A milk contains 4 per cent. of fat and the Quevenne lactometer reading is 32. What it the amount of total solids in the milk?

We multiply the amount of fat, 4, by 1.2; it equals 4.8. Then, we find one-fourth of the lactometer reading (32), which equals 8. Then we add 4.8 and 8 and get the result, 12.8, as the amount of total solids in milk.

CHAPTER XII.

SPECIAL DAIRY PRODUCTS.

In America most of our milk is consumed in one of the following forms: (1) Directly as milk, (2) as cream, (3) in the form of butter, and (4) in the form of cheese. To some extent, there are, in addition, special products prepared from milk for a more or less limited market. Some of these special products are finding an increasing importance in trade and others promise to become additional sources for the increased use of consumers in those special forms. In some of these special dairy products, it is easily possible for an enterprising dairyman to create a local trade.

92. Special Milk Preparations.

(1.) Blended Milk is modified normal milk, made from normal milk, (a) by adding cream or (b) by removing a limited amount of fat, or (c) by adding a limited amount of fresh skim-milk, or (d) by adding cream and skim-milk at the same time. It is a violation of the statutes of many States to sell blended milk as normal milk, except when cream has been added to normal milk. Blended milk, however prepared, is really a special preparation and should always be sold, not as normal milk, but as a special preparation with a guarantee as to its composition. The most common form of legitimate blended milk is the addition of cream to normal milk to such an extent as to bring the fat in the milk up to five per cent. The advantage of such milk is its uniformity in composition. It is usually supplied to a limited trade at higher prices than prevail for normal milk. Generally ,such milk is also prepared under every precaution of cleanliness from the stable to the delivery to the consumer. When thus prepared, it is often called "sanitary" milk, and each bottle is labeled with a guarantee of purity.

(2.) Modified Milk is milk so prepared as to make it resemble human milk in composition as nearly as possible. Such preparations are made in milk laboratories and their consumption is largely con-

fined to cities and hospitals. Such milk should be used only by the prescription of a physician. In general, cows' milk contained more fat and sugar, and less casein, albumin and ash than human milk. The following description serves to give an idea of how such preparations are made. The milk is cooled at once after milking, its amount of fat determined, and it is then diluted with an equal bulk of boiled water. This mixture is then run through a separator. By this process the liquid coming from the cream spout can be made to give a product higher in fat in relation to casein and albumin than in the normal cows' milk and closely approximating their amounts in human milk. To 100 pounds of this product are added about two pounds of milk-sugar.

(3.) Condensed Milk is usually prepared by evaporating water from normal milk in vacuum pans to a pasty consistency. Uusually, more or less cane sugar is added to it and, when so treated, it is often called "conserved" milk. Only milk that has been carefully produced in respect to cleanliness is used for condensing. The following analyses give the composition of some condensed milks:

	Per cent. of water.	Per cent. of solids.	Per cent. of fat.	Per cent. of casein and albumin.	Per cent. of sugar.	Per cent. of ash.
Condensed milk without added sugar,.....	59.0	41.0	12.4	11.9	14.5	2.2
Condensed milk with added sugar, ...	25.6	74.4	10.4	11.8	50.0	2.2

Condensed milk is used only where fresh milk cannot be obtained, or where fresh milk is unsatisfactory in quality, and its use is, therefore, somewhat limited, but it furnishes an added outlet for the milk producer.

93. Special Varieties of Cheese.

There are made in America and Europe more than 150 different kinds of cheese. In this country most of the cheese made is the cheddar variety, but there are prepared, to a limited extent, several other kinds, some of which are successful imitations of foreign varieties of the same name. American *home-trade* cheese is usually made by the "stirred curd" or "granular" process and resembles cheddar cheese in general qualities, except that it is made to hold somewhat more moisture. *Sage* cheese is ordinary cheddar cheese containing

an extract of sage leaves, imparting a characteristic flavor and light greenish color. *Pineapple* cheese is a firm, solid cheese, pressed into a shape resembling a pineapple. *American Neufchatel* cheese is a soft cheese, with a rather high water content, made from sweet normal milk; it must be consumed at once within two to four weeks after being made. It comes into market in small round forms, covered with paper and then tinfoil. *Philadelphia* cream cheese is a soft, moist cheese, somewhat resembling Neufchatel, but is made from cream and put on the market in thin, flat cakes, wrapped in parchment paper. There are also made in America, Edam, Limburger, Swiss, Brie, Camenbert, Gouda and other varieties. *Primost* or *whey* cheese is practically condensed whey, containing added cream, and pressed in the form of brick-shaped cakes. *Cheese-Food* is a form of cheese that contains all the solid constituents of milk. It is made in Wisconsin. In preparing it, an ordinary cheddar cheese is first made and cured; to about 100 pounds of this is added whey, evaporated to a syrupy consistency, from about 1,000 pounds of fresh whey. The mixture of cheese and evaporated whey is ground to a pasty consistency and pressed into cakes of convenient size. This cheese-food has good keeping quality and is very palatable, being mildly cheese-like in flavor and sweetish in taste. There are two other preparations to which more precise attention is called, because they offer to small factories and farm dairies an opportunity for working up local trade. These are cottage cheese and potted cheese, or club cheese.

(1.) *Cottage Cheese* is known under several names, such as Dutch cheese, pot-cheese, schmierkäse, etc. Much of what comes into market is poorly made; properly made, cottage cheese is a delicious and nutritious article of diet, which can be readily eaten by many people who are unable to digest other cheese. Cottage cheese is usually made from skim-milk or buttermilk. The milk is allowed to sour, this process being hastened, if desired, by keeping the milk at a temperature of 80 degrees F. until well coagulated. If allowed to stand too long, the curd is likely to become soft and mushy in consistency and too sour in flavor, resulting in an unsatisfactory product. When well coagulated, the temperature is gradually raised and the coagulated mass is stirred, thus breaking the curd into small pieces, from which moisture is more readily expelled. The temperature is gradually raised to 120 degrees F. and the stirring is continued. When the curd is sufficiently firm, it is allowed to settle. Then the whey is removed and the curd dipped into a cloth strainer that can be suspended, and the excess of whey is allowed to drain from the curd, the process being facilitated by occasional stirring. After becoming sufficiently dry, the curd is salted

to taste, and, if a desirable article is to be made, it should have mixed into it a little cream or melted butter. It can be put up in various forms for the market, the chief requirement being that it shall have an attractive appearance.

A cottage cheese of less acid character can be made by taking milk that is only mildly sour and using a little rennet extract to hasten the coagulation. In this case the temperature used in expelling the whey need not be so high.

(2.) *Potted Cheese, or Club Cheese.*—This is on the market under various brand names, such as Club House, Canadian Club, Meadow Sweet, etc., being put up in small jars. This cheese is very easily prepared on a small scale. Take a piece of any good well-ripened cheese, pare off the rind, cut the cheese into small chunks and pass them through a meat-grinding machine. To the cheese thus ground, one adds one ounce of melted butter of good quality for each pound of cheese and works it through the cheese until thoroughly incorporated. Then take small jars or jelly glasses, cover the inside with a layer of melted butter and pack into them the cheese, filling nearly level full. Then cover the exposed surface with melted butter and put over this a cover of paper. Set away in a cool place until wanted for use. The writer knows of cases where small dairy farms make cheese and put the product on to the local market in this form with great success. Any housekeeper can easily put up cheese in this way. Cheese put up in this way has, for the consumer, several advantages, since it does not dry out before being used up, is in convenient form to set directly on the table, is exceedingly palatable and is soft enough to be spread on bread or crackers, if desired.

94. Special Dairy Beverages.

The value of whole-milk, of skim-milk and of buttermilk as beverages has been long well known, supplying, as they do, readily digestible nutrition and quenching thirst, at the same time. There is one preparation of milk which deserves more attention as a common beverage that it has received, and that is koumiss, prepared from cows' milk. Its use is now largely confined to invalids, but it is a most desirable beverage for well people. In no form of preparation does milk seem so easily digestible, even in weak stomachs, as in the form of koumiss. People can drink *koumiss*, who can not use ordinary milk. It can be easily prepared in any household and any dairyman could work up a good local trade in it, after once getting a start. Many people do not like koumiss at first, but readily acquire a taste for it and become exceedingly fond of it. A good article of koumiss can be prepared, on a small scale, as follows: To three quarts of fresh milk, add three level tablespoonfuls of

ordinary granulated sugar and one fresh compressed yeast cake (Fleischmann's), or an equivalent of any other form of yeast. Stir it thoroughly and warm the milk up to 100 degrees F. to 105 degrees F., and keep it at that temperature, stirring from time to time, until the yeast begins to work, which is shown by little bubbles of gas escaping from the surface of the milk. This may require from three to five hours, according to the activity of the yeast. When the yeast is working well, pour the milk into pint beer bottles or some similar bottle that will stand pressure and has a convenient arrangement for corking. Fill the bottles only two-thirds full. Then put in stoppers and place the bottles in a warm place at 90 degrees F. to 100 degrees F. for half an hour. Then place at once in a cold refrigerator or directly on ice, laying the bottles down on their sides. In twenty-four hours, the koumiss is ready to begin to use. If one have good yeast and keeps the temperature at 100 degrees F., there should be no trouble in making excellent koumiss. Koumiss a week old is usually too acid for the taste of some people. In opening a bottle of koumiss after it is one or two days old, it is well to perform the operation in the kitchen rather than in the dining room, since there is usually such a pressure of accumulated gas in the milk that it may come out with a rush, especially if the contents of the bottle have been shaken just before opening. Milk from which half the fat has been removed or fresh separator skim-milk makes good koumiss.

INDEX.

A.

Page.

Abnormal fermentations, ... 27
Accuracy of Babcock test glassware, ... 102
Acid, action of, on casein, ... 18
Acid, action of, on curd, ... 73
Acid, action of, on paracasein, ... 73
Acid, action of, on rennet, ... 66
Acid, butyric, fermentation, ... 26
Acid, butyric, in milk-fat, ... 13
Acid, lactic, amount of, in cream ripening, ... 44
Acid, lactic, fermentation, ... 25
Acid, lactic, in cheese-making, ... 68
Acid, lactic, in butter-making, ... 57
Acid, lactic, how produced in cream-ripening, ... 42
Acid, lactic, in milk for cheese-making .. 65
Acid, lactic, in whey, ... 97
Acid, lactic, measuring by hot iron, ... 74
Acid, lactic, source of, ... 25
Acid, lactic, union of, with paracasein, 73, 74
Acid, measure for, ... 102
Acid, myristic in milk-fat, ... 13
Acid, oleic in milk-fat, ... 13
Acid, palmitic in milk-fat, ... 13
Acid, sulphuric in Babcock test, ... 103
Acid, test, Farrington's, ... 112
Acid, test, Mann's, ... 112
Acidity of cream, testing, ... 111
Acidity of milk, testing, ... 111
Adulterated milk, detection of by lactometer, ... 114
Aeration of milk, ...30, 64
Aerators, milk, ... 30
Agriculture, dairying a branch of, ... 9
Albumin, action of acids on, ... 19
Albumin, action of heat on, ... 19
Albumin in buttermilk, ... 57
Albumin in cheese, ... 91
Albumin in condensed milk, ... 116
Albumin in milk, ... 19
Albumin in skim-milk, ... 38
Albumin in whey, ... 97
Albumin not acted on by rennet, ... 19
Alcoholic fermentation in milk, ... 27
Alkalies, action of, on casein, ... 18
Alkaline, effect of, on action of rennet, .. 67
Alkaline tablet test, Farrington's, ... 112
American cheese, Brie, ... 117
American cheese, Camembert, ... 117
American cheese, Cheddar, composition of 98
American cheese, Cheddar, manufacturer of 69
American cheese, Edam, ... 117
American cheese, Gouda, ... 117
American cheese, Limburger, ... 117
American cheese, Neufchatel, ... 117
American Holderness cows, fat in milk of 15
American Holderness cows, solids in milk of, ... 12
American Holderness cows, water in milk of, ... 12
Amount of rennet used, ... 70
Analyses of butter, ... 41
Analyses of buttermilk, ... 57
Analyses of cheese, ... 98
Analyses of condensed milk, ... 116
Analyses of cream, ... 32
Analyses of milk, ... 20
Analyses of separator slime, ... 40
Analyses of skim-milk, ... 38
Analyses of whey, ... 97
Animal ordor in milk, ... 30
Antiseptics, ... 23
Apparatus for Babcock test, ...101, 102
Apparatus for Farrington's test, ... 112
Apparatus for Mann's test, ... 112
Art, dairying as an, ... 9

Page.

Ash, amount in butter, ... 41
Ash, amount in buttermilk, ... 57
Ash, amount in cheese, ... 98
Ash, amount in condensed milk, ... 116
Ash, amount in cream, ... 32
Ash, amount in milk, ... 20
Ash, amount in separator slime, ... 40
Ash, amount in skim-milk, ... 38
Ash, amount in whey, ... 97
Ayrshire cows, fat in milk of, ... 15
Ayrshire cows, solids in milk of, ... 12
Ayshire cows, water in milk of, ... 12

B.

Babcock test, acid measure, ... 102
Babcock test, advantages of, ...100, 101
Babcock test, apparatus for, ...101, 102
Babcock test, bottles, ...101, 107, 109
Babcock test, centrifugal machines, ... 102
Babcock test, details of, ...103, 107
Babcock test, disadvantages of, ... 101
Babcock test, rule for ascertaining solids, 114
Bacillus, ... 22
Bacteria, ... 22
Bacteria, changes produced by, ... 23
Bacteria, delaying growth of, in milk, .. 28
Bacteria, destroyed by chemicals, ... 23
Bacteria, destroyed by heat, ... 23
Bacteria, destroying in milk, ... 30
Bacteria, effect of cold on, ... 22
Bacteria, effect of sunlight on, ... 23
Bacteria, food of, ... 22
Bacteria, found everywhere, ... 23
Bacteria in air of stable, ... 24
Bacteria in dirt, ... 24
Bacteria in milk cans, ... 24
Bacteria in milk pails, ... 24
Bacteria in strainers, ... 24
Bacteria in udder cavity, ... 24
Bacteria in whey-vat, ... 24
Bacteria, keeping out, of milk, ... 28
Bacteria, kinds of, found in milk, ... 25
Bacteria, milkers as sources of, ... 24
Bacteria, number in milk, ... 24
Bacteria on cows, ... 24
Bacteria producing rancid butter, ... 26
Bacteria, rapidity of growth, ... 22
Bacteria, sources of, in milk, ... 24
Bacteria, spores of, ... 23
Bacteria, taints in milk from, ... 25
Bacteria, temperature favorable for, ... 22
Bandaging cheese, ... 77
Beverages, dairy, ... 118
Bitter milk, ... 27
Blended milk, ... 115
Blue milk, ... 27
Board of Health lactometer, ... 114
Body of cheese, ... 87
Bottles of Babcock test, ...101, 107, 109
Brine-salting of butter, ... 53
Butter, amount of buttermilk left in, ... 49
Butter, amount of, made for one pound of milk-fat, ... 59
Butter, analyses of, ... 41
Butter, ash and salt in, ... 41
Butter, brine-salting of, ... 53
Butter, casein in, ... 41
Butter, color of, ... 55
Butter, composition of, ... 41
Butter, effect of washing, ... 51
Butter-fat, see milk-fat.
Butter, flavor of, ... 54
Butter, general appearance of, ... 56
Butter granules, ... 49
Butter granules, removing buttermilk from, ... 50

Page.

Butter, hardness of, in relation to myristin, ... 14
Butter, hardness of, in relation to palmitin, ... 14
Butter, moisture in, ...41, 56
Butter, mottled and streaked, ... 53
Butter packages, ... 54
Butter packing for markets, ... 53
Butter prints, ... 54
Butter, qualities of, ... 54
Butter, rancid, ... 26
Butter, relation of milk to yield of, ... 57
Butter, relation of milk-fat to yield of, .. 58
Butter, salt in, ... 55
Butter, salting, ... 52
Butter, softness in relation to butyrin, .. 14
Butter, softness in relation to olein, ... 14
Butter, solidity of, ... 56
Butter, sweet-cream, ... 42
Butter, texture of, ... 55
Butter, water in, ... 41
Butter, white specks in, ... 44
Butter, working, ... 52
Butter yield, measure of losses in manufacture, ... 59
Butter-making, ... 40
Butter-making, distribution of milk-fat in, ... 57
Butter-making, losses in, detected by yield of butter, ... 59
Butter-making, ripening cream for, ... 41
Buttermilk, albumin in, ... 57
Buttermilk, analyses of, ... 57
Buttermilk, casein in, ... 57
Buttermilk, composition of, ... 57
Buttermilk, fat in, ... 57
Buttermilk left in butter, ... 49
Buttermilk, removal from granules, ... 50
Buttermilk, testing, ... 108
Buttermilk, water in, ... 57
Butyric acid fermentation, ... 26
Butyric acid in milk-fat, ... 13
Butyrin, effect in softening of butter, .. 14
Butyrin, in milk fat, ... 14
Butyria, melting point of, ... 14

C.

Camembert cheese, ... 117
Carbon dioxide gas in milk, ... 20
Casein, action of acids on, ... 18
Casein, action of alkalies on, ... 18
Casein, action of formalin on, ... 18
Casein, action of galactase on, ... 19
Casein, action of heat on, ... 19
Casein, action of rennet on, ... 19
Casein, action of salt on, ... 18
Casein, amount of, in milk, ... 29
Casein, composition of, ... 18
Casein, fermentation of, ... 26
Casein in butter, ... 41
Casein in buttermilk, ... 57
Casein in condensed milk, ... 116
Casein in milk, ... 18
Casein in separator slime, ... 40
Casein, in skim-milk, ... 40
Casein in whey, ... 97
Casein, influence of lactation on, ... 19
Casein, loss of, in cheese-making, ... 92
Casein not in solution, in milk, ... 18
Casein, relation of, to milk-fat, ... 89
Centrifugal machines for separating cream, ... 35
Centrifugal machines for Babcock test, .. 102
Centrifugal separation of cream, ... 34
Centrifugal separation of cream, theory of, ... 35
Cheddar cheese, manufacture of, ... 69
Cheddaring curd, ...74, 75
Cheese, American cheddar, ... 69
Cheese as cheap food, ... 99
Cheese, ash, salt, etc., in, ... 98
Cheese as source of protein, ... 99
Cheese, bandaging, ... 77
Cheese, body of, ... 87
Cheese, Brie, ... 117
Cheese, club, ... 118
Cheese, color of, ... 88
Cheese, composition of, ... 98
Cheese, concentrated food, ... 98
Cheese, cottage, ...40, 117
Cheese, cream, ... 94
Cheese curing, changes caused by, ... 79
Cheese curing, loss of moisture, ... 79

Page.

Cheese curing rooms, ...82, 83, 84
Cheese curing, temperature for, ... 80
Cheese, Edam, ... 117
Cheese factories, paying for milk at, ..95, 96, 97
Cheese, fat in, ... 98
Cheese, flavor of, ... 87
Cheese food, ... 117
Cheese, gas-forming fermentations in, .. 77
Cheese, general appearance of, ... 88
Cheese, Gouda, ... 117
Cheese, home-trade, ... 116
Cheese, huffing, ... 26
Cheese, Limburger, ... 117
Cheese, moisture in rooms for curing, ... 117
Cheese, Neufchatel, ... 117
Cheese, paracasein in, ...71, 98
Cheese, Philadelphia cream, ... 117
Cheese, pineapple 117
Cheese, "pinholes" in, ... 77
Cheese, poison, ... 26
Cheese, potted, ... 118
Cheese, primost, ... 117
Cheese, qualities of, ... 86
Cheese, quality of, in relation to milk, .. 94
Cheese, quick-curing, rennet in, ... 71
Cheese, relation of milk to, ... 88
Cheese, sage, ... 116
Cheese, sizes of, ... 78
Cheese, skim-milk, ... 94
Cheese, slow-curing, rennet in, ... 71
Cheese, solids in, ... 98
Cheese, special varieties of, ... 116
Cheese, standard composition for, ... 95
Cheese, stirred-cured, ... 69
Cheese, Swiss, ... 117
Cheese, testing, ... 109
Cheese, texture of, ... 87
Chese, value of, as food, ... 98
Cheese, water in, ... 98
Cheese whey, ... 117
Cheese yield in relation to fat in milk, .. 90
Cheese yield in relation to milk, ... 88
Cheese-making, aerating milk for, ... 64
Cheese-making, care of milk for, ... 63
Cheese-making, cheddaring curd, ... 74
Cheese-making, common troubles in, ... 77
Cheese-making, cooking curd, ... 73
Cheese-making, cooling milk for, ... 63
Cheese-making, distribution of milk constituents 91
Cheese-making, fat in whey in, ... 89
Cheese-making, fat lost in, ... 91
Cheese-making, grinding curd, ... 76
Cheese-making, heating, ... 72
Cheese-making, lactic in milk for, ... 65
Cheese-making, loss of casein in, ... 92
Cheese-making, losses of milk constituents in, ... 92
Cheese-making, matting curd 74
Cheese-making, method of adding rennet, 71
Cheese-making, milling curd, ... 76
Cheese-making, overripe milk in, ... 78
Cheese-making, preliminaries of, ... 63
Cheese-making, pressing curd. 76
Cheese-making, quality of milk for, ... 92
Cheese-making, ripening of milk for, .. 68
Cheese-making, setting milk, ... 70
Cheese-making, salting curd, ... 76
Cheese-making, undesirable fermentation, 77
Cheese-making, use of starters in, ... 68
Chemical action of rennet, ... 66
Chemistry of milk, ... 10
Chemistry of water, ... 11
Churning, ... 46
Churning affected by food of cows, ... 47
Churning affected by individuality, ... 47
Churning affected by stage of lactation,.. 47
Churning affected by ripeness of cream, .. 47
Churning affected by season of year, ... 47
Churning affected by thickness of cream, 47
Churning, completeness of, ... 49
Churning, conditions affecting, ... 47
Churning, causes of difficulties in, ... 49
Churning, relation of fat-globules to, ... 46
Churning, relation of milk-serum to, ... 47
Churning, relation of ripeness of cream to, 47
Cheese, temperature of, ... 47
Churning, when to stop, ... 48
Churns, kinds of, ... 48
Cleansing tinware, ... 28
Cleansing utensils, ... 28
Cleanliness of milk, ... 28
Club cheese, ... 118
Coagulation of milk by casein, ... 70

Page.

Coccus, ... 22
Cold, effect on bacteria, ... 22
Color of butter, ... 55
Color of cheese, ... 88
Color of milk-fat, ... 14
Composite samples, ... 110
Composition of butter, ... 41
Composition of buttermilk, ... 57
Composition of casein, ... 18
Composition of cheese, ... 98
Composition of condensed milk, ... 116
Composition of cream, ... 32
Composition of milk, ... 20
Composition of milk and quality of cheese, 94
Composition of separator slime, ... 40
Composition of skim-milk, ... 38
Composition of skim-milk cheese, ... 93
Composition of whey, ... 97
Condensed milk, albumin in, ... 116
Condensed milk, ash in, ... 116
Condensed milk, casein in, ... 116
Condensed milk, composition of, ... 116
Condensed milk, fat in, ... 116
Condensed milk, sugar in, ... 116
Condensed milk, testing, ... 109
Condensed milk, water in, ... 116
Constituents of milk, ... 10, 20
Contagious diseases in relation to milk, 29
Contamination of milk, ... 21
Cooked taste of heated milk, ... 31
Cooking curd, ... 73
Coolers, milk, ... 30
Cooling milk for cheese-making, ... 63
Cottage cheese and skim-milk, ... 40, 117
Cows' milk, composition of, ... 10, 20
Cows, care in keeping clean, ... 28
Cows, effect of age on fat in milk, ... 16
Cows, effect of age on water in milk, 16
Cows, effect of lactation period on milk, 16
Cows, source of bacteria, ... 24
Cream, ... 32
Cream, analyses of, ... 32
Cream cheese, ... 94
Cream, composition of, ... 32
Cream, fat in, ... 32
Cream, frothing or swelling, ... 50
Cream, fat-globules in, ... 32
Cream, gravity separation, ... 32
Cream, mixing, of different ages, ... 46
Cream, overripened, ... 44
Cream, pasteurized, artificial thickening of, ... 37
Cream, pasteurizing for butter-making, 45
Cream, profits of selling, ... 37
Cream, regulating thickness of, ... 36
Cream, richness of, for butter-making, .. 46
Cream, ripening of, for churning, ... 47
Cream, ripening, amount of lactic acid for, ... 44
Cream, ripening effects produced by, ... 44
Cream, ripening for butter-making, ... 41
Cream, ripening lactic acid, how produced, ... 42
Cream, ropy fermentation of, ... 27
Cream, separation of, from milk, ... 32
Cream, separation by centrifugal force, 34
Cream, separation by deep-setting, ... 33
Cream, separation by shallow pans, ... 33
Cream, slimy fermentation of, ... 27
Cream, starter in ripening, ... 43
Cream, testing fat of, ... 107
Cream, testing acidity of, ... 111
Creameries, calculating dividends at, ... 60, 61
Creameries, paying dividends at, on basis of milk-fat, ... 59
Creaming by gravity, conditions affecting, 34
Creaming, efficiency of separators, ... 36
Creaming, shallow-pan, disadvantages of, 33
Curd, cheddaring, ... 74
Curd, cutting, ... 72
Curd, grinding, ... 76
Curd, heating or cooking, ... 73
Curd, hot-iron test for, ... 74
Curd, how to cut, ... 72
Curd knife, horizontal 72
Curd knife, perpendicular, ... 72
Curd, matting, ... 74
Curd, milling, ... 76
Curd, piling, ... 74, 75
Crud, "pin-holey," 77
Curd, pressing, ... 76, 77
Curd racks, ... 75

Page.

Curd, removing whey from, ... 74
Curd, salting, ... 76
Curd, shrinking of, ... 73
Curd sink, ... 75
Curd, strings formed on hot-iron by, ... 74, 76
Curd, test, Wisconsin, ... 64, 65
Curd, when to cut, ... 72
Curd, when to remove whey, ... 74
Curds, fast-working, ... 78
Curds, "floating," 26, 77
Curds "gassy," 26, 77
Curing cheese, changes caused by, ... 79
Curing cheese, moisture in air for, ... 80, 84
Curing cheese, temperature for, ... 80
Curing rooms, central, ... 81
Curing rooms, constuction of, ... 81
Curing rooms, location of, ... 81
Curing rooms, sub-earth ducts in, ... 85
Curing rooms, ventilation of, ... 84
Cutting the curd, ... 72

D.

Dairy beverages, ... 118
Dairy salt, ... 53
Dairy utensils, cleaning, ... 28
Dairying as an art, ... 9
Dairying as a branch of agriculture, ... 9
Dairying as a manufacturing industry, .. 9
Dairying as a science, ... 9
Dairying, changes in, ... 10
Dairying, objects of, ... 9
Devon cows, fat in milk of, ... 15
Devon cows, solids in milk of, ... 12
Devon cows, water in milk of 12
Diphtheria germs in milk 27
Diarrhoeal disease germs in milk, ... 27
Digesting enzymes, ... 26
Dipping whey, ... 74
Dirt and bacteria, ... 24
Diseases, contagious germs of, in milk, 28
Disease germs in milk, ... 27
Disinfectants, ... 23
Dissolving enzymes, ... 26
Distribution of milk constituents in butter-making, ... 57
Distribution of milk constituents in cheese-making, ... 91
Dividends calculating at creameries, ... 60
Dividends calculating at cheese factories, 97
Drawing whey, ... 74
Dutch cheese, ... 117
Dust, relation of bacteria to, ... 24, 28

E.

Edam cheese, ... 117
Effects produced by ripening cream, ... 44
Enzymes, ... 23
Enzymes, digesting, ... 26
Enzymes, dissolving, ... 26
Enzymes, galactase, ... 19, 23
Enzymes, pepsin in rennet,, ... 23
Enzymes, relation of, to cheese-ripening, ... 19, 80
Extract, rennet, ... 65, 67

F.

Farrington's alkaline tablets, ... 112
Fast-working curds, ... 78
Fat affected by age of cows, ... 16
Fat affected by breed of cows, ... 15
Fat affected by different portions of milking, ... 17
Fat affected by food, ... 16
Fat affected by individuality of cow, ... 15
Fat affected by lactation period, ... 16
Fat affected by time between milkings, .. 16
Fat affected by yield of milk, ... 16
Fat, amount of, in milk, ... 15
Fat as basis of value for milk in butter-making, ... 59
Fat as basis of value for milk in cheese-making, ... 95, 97
Fat, butyris acid fermentation of, ... 26
Fat globules in cream, ... 32
Fat globules in milk, ... 14
Fat glchules, no covering membrane on
Fat globules, number in milk, ... 14

Page.

Fat globules, relation of, to churning, ... 46
Fat globules, size of, ... 14
Fat globules, loss of, in cheese-making, .. 91
Fat in butter, ... 41
Fat in buttermilk, ... 57
Fat in cheese, ... 98
Fat in condensed milk, ... 116
Fat in cream, ... 32
Fat in cream raised by gravity, ... 34
Fat in foremilk and strippings, ... 17
Fat in herd milk, ... 15
Fat in separator skim-milk, ... 40
Fat in single milkings, ... 15
Fat in skim-milk, ... 40
Fat in strippings, ... 17
Fat in whey, ... 97
Fat in cheese-making, ... 89
Fat in milk of American Holderness cows, ... 16
Fat in milk of Ayrshire cows, ... 16
Fat in milk of Devon cows, ... 16
Fat in milk of Guernsey cows, ... 16
Fat in milk of Holstein cows, ... 16
Fat in milk of Jersey cows, ... 16
Fat, loss of, in cheese-making, ...89, 91
Fat, loss of, by deep-setting, ... 33
Fat, loss of, by gravity creaming, ... 33
Fat, loss of, by shallow-pan creaming, .. 33
Fat, measuring amount of, ... 106
Fat, saving of, by separators, ... 36
Ferment, Hansen's lactic acid in cheese-making, ... 69
Fermentations, abnormal, ... 27
Fermentations, alcoholic in milk, ... 27
Fermentations, butyric acid, ... 26
Fermentations, gas-forming in cheese, .. 77
Fermentations, lactic acid, ... 25
Fermentations, meaning of, ... 21
Fermentations of casein, ... 26
Fermentations, producing bitter milk, .. 27
Fermentations producing blue milk, ... 27
Fermentations producing fishy flavor, ... 27
Fermentations producing red milk, ... 27
Fermentations producing ropy cream, ... 27
Fermentations producing ropy milk,..... 27
Fermentations producing slimy cream, .. 27
Fermentations producing slimy milk, ... 27
Fermentations undesirable in cheese-making, ... 77
Ferments, conditions of activity, ... 22
injurious, detecting in milk, ... 64
Ferments organized, ... 22
Ferments, power of, ... 21
Ferments, relation of temperature to, ... 22
Ferments, two classes of, ... 22
Ferments unorganized, ... 22
Ferments, what are they, ... 21
Fishy flavor in milk, ... 27
Flats, ... 78
Flavor of butter, ... 54
Flavor of cheese, ... 87
Flavor tainted in cheese, ... 87
Floating curds, ... 26
Food of bacteria, ... 22
Food, skim-milk as, ... 39
Food, a source of taints in milk, ... 25
Food, value of cheese, ... 98
Foremilk and strippings, fat in, ... 17
Formalin, action of, on casein, ... 18
Frothing of cream, ... 50

G.

Galactase, ... 23
Galactase action on casein, ... 19
Galactase action in cheese-ripening, ... 80
Galactase in milk, ... 19
Gasses in milk, ... 20
Gas-forming fermentations in cheese, ... 77
"Gassy" curds, ...26, 77
General appearance in judging butter, .. 56
Gathered cream system, ... 59
Germs, diarrhoeal disease, in milk, ... 27
Germs, diphtheria in milk, ... 27
Germs, disease, in milk, ... 27
Germs, scarlet fever, in milk, ... 27
Germs, tuberculosis, ... 27
Germs, typhoid fever, ... 27
Glassware, accuracy of Babcock test, ... 102
Globules fat, in cheese-making, ... 91
Globules, fat in cream, ... 32

Page.

Globules, fat in milk, ... 14
Globules, fat in whey, ... 91
Globules fat, no covering membrane on, 14
Globules fat, number in milk, ... 14
Globules fat, relation of, to churning, ... 46
Globules fat, size of, ... 14
Globules fat, loss of, in cheese-making, .. 91
Glycerin in butter-fat, ... 14
Glycerin in milk-fat, ... 14
Gouda cheese, ... 117
Grain of butter, ... 55
Granules, butter, size of, ... 49
Gravity creaming, conditions affecting, .. 34
Gravity cream-raising, ... 33
Gravity, skim-milk, composition of, ... 38
Grinding curd, ... 76
Guernsey cows, fat in milk of, ... 15
Guernsey cows, solids in milk of..... 15
Guernsey cows, water in milk of, ... 12

H.

Hansen's lactic ferment, ... 69
Heat, action of, on albumin, ... 19
Heat, action of, on casein, ... 19
Heat, bacteria destroyed by, ... 22
Heated milk, skin formed on, ... 19
Heating curd in cheese-making, ... 73
Holstein cows, fat in milk of, ... 15
Holstein cows, solids in milk of, ... 12
Holstein cows, water in milk of, ... 12
Home-trade cheese, ... 116
Horizontal curd-knife, ... 72
Hot-iron test for curd, ... 74
Huffing cheese, ... 26
Hygrometer, ... 81

I.

Imitation Swiss cheese, ... 117
Industry, manufacturing, dairying as a, 9

J.

Jersey cows, fat in milk of, ... 15
Jersey cows, solids in milk of, ... 12
Jersey cows, water in milk of, ... 12

K.

Knife, curd, horizontal, ... 72
Knife, curd, perpendicular, ... 72
Koumiss, ... 118

L.

Lactic acid, ...20, 21
Lactic acid, amount of, in cream ripening, ... 44
Lactic acid, determination of, ... 111
Lactic acid, fermentation, ... 25
Lactic acid, ferment, Hansen's, ... 69
Lactic acid in buttermilk, ... 57
Lactic acid in cream ripening, how produced, ... 42
Lactic acid in milk, ... 21
Lactic acid in milk for cheese-making, .. 65
Lactic acid in whey, ... 97
Lactic acid, union of, with paracasein, .. 73
Lactometer, Board of Health, ... 114
Lactometer, comparison of scales, ... 114
Lactometer, corrections for temperature, 113
Lactometer in testing milk, ... 113
Lactometer, use of, in estimating solids, 114
Lactometer, use of, in estimating solids-not-fat, ... 114
Lactometer, value of, in detecting adulterated milk, ... 114
Lactometer, Quevenne, ... 113
Lactometer, Quevenne scales, comparison of, ... 113
Limburger cheese, ... 117
Loss of casein in cheese-making, ... 92
Loss of fat, ... 91
Loss of milk constituents in cheese-making, ... 90
Loss in butter-making detected by yield of butter, ... 59

M.

Page.

Machines, centrifugal, for separating cream, ... 35
Machines, centrifugal for Babcock test, .. 102
Making butter, ... 40
Making cheese, ...63, 69
Mann's acid test, ... 112
Manufacturing industry, dairying as, .. 9
Market, packing butter for, ... 53
Market, preparation of milk for, ... 27
Marschall rennet test, ... 68
Matting curd, ... 74
Measure for acid, ... 102
Membrane not present on fat-globules, .. 14
Methods of testing milk, ... 99
Melting point of butyrin, ... 14
Melting point of myristin, ... 14
Melting point of olein, ... 14
Melting point of palmitin, ... 14
Milkers, source of bacteria in milk, ... 24
Milling curd, ... 76
Milk, abnormal fermentations of, ... 27
Milk, adulteration, detection by lactometer, ... 114
Milk aerating for cheese-making, ... 64
Milk aerators, ... 30
Milk, alcoholic fermentation of, ... 27
Milk, animal ordor of, ... 30
Milk, ash in, ... 20
Milk, bacteria in, from dairy utensils, .. 24
Milk, bitter, ... 27
Milk, blended, ... 115
Milk, blue, ... 27
Milk, bottles for testing, ...101, 107, 109
Milk, butyric acid, fermentation in, ... 26
Milk cans and bacteria, ... 24
Milk, carbon dioxide in, ... 20
Milk, care of, for cheese-making, ... 63
Milk, casein in, ... 18
Milk casein, loss of, in cheese-making, .. 92
Milk, cheese-producing solids in, ... 91
Milk, chemistry of, ... 10
Milk, cleanliness of, ... 28
Milk coagulating by rennet, ... 70
Milk, composition of, ... 20
Milk, composition of, in relation to quality of cheese, ... 94
Milk, composition of, in relation to yield of cheese, ... 92
Milk, condensed, ... 116
Milk constituents lost in cheese-making, 90
Milk, constituents of, ... 10
Milk constituents, distribution of, in butter-making, ... 57
Milk constituents, distribution of, in cheese-making, ... 91
Milk, contamination of, ... 21
Milk, control of fermentations in, ... 27
Milk, cooked taste of, ... 31
Milk coolers, ... 50
Milk cooling for cheese-making, ... 63
Milk, delaying growth of bacteria in, ... 29
Milk, destroying bacteria in, ... 30
Milk, detecting injurious fementations in, 64
Milk, diarrhoeal disease germs in, ... 27
Milk, diphtheria germs in, ... 27
Milk, disease germs in, ... 27
Milk, effect of breed on composition of,....11, 15
Milk, effect of period of lactation on, ..12, 16
Milk fat, amount of butter made from one pound of, ... 59
Milk fat as basis of paying for milk at cheese factories, ... 95
Milk fat as basis of paying for milk at creameries, ... 59
Milk fat, butyric acid, fermentation in, 26
Milk fat, color of, ... 14
Milk fat, composition of, ... 13
Milk fat, distribution of, in butter-making, ... 57
Milk, fat-globules in, ... 14
Milk, fat in form of globules, ... 14
Milk fat lost in butter-making, ... 57
Milk fat lost in cheese-making, ... 89
Milk fat lost in churning, ... 57
Milk fat lost in creaming, ... 59
Milk fat, ordor of, ... 14
Milk fat in relation to casein, ... 89
Milk fat in relation to yield of butter, ... 58
Milk fat in relation to yield of cheese, .. 90
Milk fat, structure of, ... 14

Page.

Milk fat, taste of, ... 14
Milk, fermentation of casein in, ... 26
Milk, fishy flavor of, ... 27
Milk, gases in, ... 20
Milk in relation to yield of butter, ... 57
Milk in relation to yield of cheese, ... 88
Milk, kinds of bacteria found in, ... 25
Milk, lactic acid, fermentation of, ... 25
Milk, lactic acid in forcheese-makeup, .. 65
Milk, lactometers in testing, ... 113
Milk, methods of testing, ... 99
Milk, modified, ... 115
Milk, nitrogen compounds in, ... 20
Milk, number of bacteria in, ... 24
Milk, number of proteids in, ... 17
Milk of different cows, action of rennet on, ... 67
Milk, overripe in cheese-making, ...69, 78
Milk, oxygen in, ... 20
Milk pails and bacteria, ... 24
Milk, paying for, at cheese-factories, .. 95
Milk, paying for, at creameries, ... 59
Milk, pasteurizing, ... 31
Milk, pipette for measuring, ... 102
Milk, preparation of, for market, ... 27
Milk, quality for cheese-making, ... 94
Milk, red, fermentation of, ... 27
Milk, relation of viscosity to churning, .. 50
Milk, relation to quality of cheese, ... 94
Milk, relation to yield of butter, ... 57
Milk relation to yield of cheese, ... 95
Milk, removal from stable, ... 28
Milk, ripening for cheese-making, ... 68
Milk, ropy fermentation of, ... 27
Milk, sampling for testing, ... 103
Milk, scarlet fever germs in, ... 27
Milk serum, composition of, ... 20
Milk serum in relation to churning, ... 50
Milk, slimy fermentation of, ... 27
Milk-solids, ... 20
Milk-solids in cheese-making, ... 91
Milk-solids in milk of American Holderness cows, ... 12
Milk-solids in milk of Ayrshire cows, .. 12
Milk-solids in milk of Devon cows, ... 12
Milk-solids in milk of Guernsey cows, .. 12
Milk-solids in milk of Holstein cows, ... 12
Milk-solids in milk of Jersey cows, ... 12
Milk-solids in milk of Shorthorn cows, .. 12
Milk-solids, use of lactometer in estimating, ... 114
Milk, sources of bacteria in, ... 24
Milk, souring of, ... 25
Milk, specfic gravity of, ... 113
Milk sterile, advantages of, ... 31
Milk sterile, disadvantages of, ... 31
Milk sterilizing, ... 31
Milk, straining, ... 29
Milk, strength of rennet in coagulating, 66
Milk-sugar in buttermilk, ... 57
Milk-sugar in cheese, ... 91
Milk-sugar in condensed milk, ... 116
Milk-sugar in cream, ... 32
Milk-sugar in milk, ... 20
Milk-sugar in separator slime, ... 40
Milk-sugar in skim-milk, ... 38
Milk-sugar in whey, ... 97
Milk-sugar, source of lactic acid, ... 20
Milk, temperature of, when adding rennet, ... 70
Milk test, Babcock, ... 100
Milk, testing acidity of, ... 111
Milk, to determine degree of ripeness of, 69
Milk, typhoid fever germs in, ... 27
Milk, viscosity of, ... 34
Milk, viscosity of, in relation to churning, 50
Milk, water in, of American Holderness, cows, ... 12
Milk, water in, of Ayrshire cows, ... 12
Milk, water in, of Devon cows, ... 12
Milk, water in, of Guernsey cows, ... 12
Milk, water in, of herds of cows, ... 11
Milk, water in, of Holstein cows, ... 12
Milk, water in, influence of age on, ... 13
Milk, water in, influence of lactation, .. 12
Milk, water in, Jersey cows, ... 12
Milk, water in, Shorthorn cows, ... 12
Milk, water in, single milkings, ... 11
Milk, whey-solids of, ... 91
Milking, cleanliness in, ... 28
Milling curd, ... 76

Page.

Modified milk, ... 115
Moisture in air of cheese curing room, .. 81
Moisture in butter, ...41, 56
Monrad rennet test, ... 67
Myristic acid in milk-fat, ... 13
Myristin in milk-fat, ... 14
Myristin, influence of, on hardness of butter, ... 14
Myrstin, melting point of, ... 14

N.

Natural starters, preparation of, ... 43
Neufchatel cheese, American, ... 117
Night's and morning's milk, difference in composition, ... 16
Nitrogen compounds, number of, in milk, 17
Nitrogen gas in milk, ... 20

O.

Odor of milk, ... 30
Odor of milk-fat, ... 14
Oleic acid in milk-fat, ... 13
Olein, effect of, on softness of butter, .. 14
Olein in milk-fat, ... 14
Olein, melting point of, ... 14
Overripe milk in cheese-making, ...69, 78
Oyxgen in milk, ... 20

P.

Packages, butter, ... 54
Packing butter for market, ... 53
Palmitic acid in milk-fat, ... 13
Palmitin, effect on hardness of butter,.. 14
Palmitin in milkfat, ... 14
Palmitin, melting point of, ... 14
Paracasein in cheese, ...71, 98
Paracasein, union of lactic acid with, .. 73
Pasteurized cream, thickening of, ... 31
Pasteurizers, ... 31
Pasteurizing, advantages of, ... 31
Pasteurizing for butter-making, ... 45
Pasteurizing milk, ... 31
Paying for milk at creameries, ... 59
Paying for milk at cheese-factories, ... 95
Pepsin in rennet, ... 23
Pepsin in rennet in cheese-curing, ... 80
Perpendicular curd-knife, ... 72
Piling curd, ... 74
Philadelphia cream cheese, ... 117
Pineapple cheese, ... 117
"Pin-holes" in cheese, ... 77
Pipette for Babcock test, ... 102
Poisonous fermentations, ... 25
Potted cheese, ... 118
Preparation of artificial starter, ... 43
Pressing cheese, ... 76
Primost, ... 117
Prints, butter, ... 54
Proteids in milk, ... 17
Protein, cheese as source of, ... 99
Profits from selling cream, ... 37
Pure-culture starters, ... 43

Q.

Qualities of butter, ... 54
Qualities of cheese, ... 86
Quality of cheese in relation to composition of milk, ... 94
Quevenne lactometer, ... 113

R.

Rancid butter, ... 26
Red milk, ... 27
Rennet, ...23, 66, 70
Rennet, action of, on casein, ... 19
Rennet, action of, on milk of different cows, ... 67
Rennet, amount used in cheese-making, 70
Rennet, chemical action of, ... 66
Rennet, coagulating milk by, ... 70
Rennet, conditions of action of, ... 66

Page.

Rennet, effect of acids on, action of, .. 66
Rennet, effect of alkalies, ... 67
Rennet, effect of chemicals, ... 67
Rennet, effect of dilution, ... 67
Rennet, effect of heat on action of, ... 67
Rennet, effect of strength on action of, .. 66
Rennet, effect of temperature, ... 66
Rennet, effect on cheese-ripening, ... 80
Rennet, enzymes contained in, ... 23
Rennet extract, ... 65
Rennet, methods of testing, ... 67
Rennet, methods of adding to milk in cheese-making, ... 71
Rennet, pepsin contained in, ... 23
Rennet, source of, ... 65
Rennet, strength of, in coagulating milk, 66
Rennet, temperature of milk when adding, ... 70
Rennet test, Marschall, ... 68
Rennet test, Monrad, ... 67
Richness of cream for butter-milking, .. 46
Ripeness, churning cream of different degrees of, ... 45
Ripeness of cream in relation to churning 47
Ripeness of milk, to determine degree of in cheese-making, ... 69
Ripening cream for butter-making, ... 41
Ripening cream, amount necessary, ... 44
Ripening cream, relation of temperature to, ... 43
Ripening cream, use of starters in, ... 43
Ripeness, milk for cheese-making, ... 68
Ropy cream, ... 27
Ropy milk, ... 27

S.

Sage cheese, ... 116
Salt, action of, on casein in milk, ... 18
Salt, dairy, ... 53
Salt in butter, ... 55
Salt in cheese, ... 76
Salt, influence of, on cheese-curing, ... 76
Salting butter, ... 52
Salting curd, ... 76
Samples, composite, ... 110
Sampling milk for testing, ... 103
Scale of perfection for butter, ... 56
Scale of perfection for cheese, ... 88
Scarlet fever germs in milk, ... 27
Schmierkase, ... 117
Science, dairying as a, ... 9
Separation of cream, ... 32
Separation of cream by centrifugal, ... 34
Separation of cream by gravity, ... 33
Separator, skim-milk, ... 37
Separator, skim-milk, composition of, ... 38
Separator, slime, ash in, ... 40
Separator, slime, casein in, ... 40
Separator, slime, composition of, ... 40
Separator, slime, fat in, ... 40
Separator, slime, milk-sugar in, ... 40
Separator, slime, water in, ... 40
Separators, advantages of, ... 36
Separators, conditions of efficiency, ... 35
Separators, creaming efficiency of, ... 36
Separators, regulating richness of cream, 36
Serum of milk, composition of, ... 20
Shallow pan system of cream-raising, ... 33
Shorthorn cows, fat in milk of, ... 15
Shorthorn cow, solids in milk of, ... 12
Shorthorn cow, water in milk of, ... 12
Size of fat-globules, ... 14
Skim-milk, albumin in, ... 38
Skim-milk and cheese, ... 93
Skim-milk and cottage cheese, ...40, 117
Skim-milk as food, ... 39
Skim-milk, ash in, ... 38
Skim-milk, casein in, ... 38
Skim-milk, cheese, ... 93
Skim-milk, composition of, ... 38
Skim-milk, fat in, ... 38
Skim-milk gravity, composition of, ... 38
Skim-milk, milk-sugar in, ... 38
Skim-milk separator, composition of, .. 38
Skim-milk, testing, ... 108
Skim-milk, uses of, ... 39
Skim-milk, water in, ... 38
Skin formed on heated milk, ... 19
Slimy fermentation of cream, ... 27

Page.

Slimy fermentation of milk, ... 27
Solidity of butter, ... 56
Solids in cheese, ... 98
Solids in milk, ... 20
Solids in milk of American Holderness cows, ... 12
Solids in milk of Ayrshire cows, ... 12
Solids in milk of Devon cows, ... 12
Solids in milk of Guernsey cows, ... 12
Solids in milk of Holstein cows, ... 12
Solids in milk of Jersey cows, ... 12
Solids in milk of Shorthorn cows, ... 12
Solids in whey, ... 97
Solids, not fat in milk, ... 20
Solids, not fat, estimation of, ... 114
Souring of milk, ... 25
Specific gravity of milk, ... 113
Spirillum, ... 22
Spores, effect of heat on, ... 23
Spores of bacteria, ... 22
Stable, air of, source of bacteria, ... 24
Stable, care of, ... 28
Stable, removal of milk from, ... 28
Standard composition of whole-milk cheese, ... 95
Starters, advantages of, ... 44
Starters, natural, preparation of, ... 43
Starters, pure-culture, ... 43
Sterile milk, ... 21
Sterilized milk, advantages of, ... 31
Sterilized milk, disadvantages of, ... 31
Stirred-curd cheese, ... 69
Strainers and bacteria, ... 24
Straining milk, ... 29
Streaked butter, ... 53
Strippings and foremilk, fat in, ... 17
Structure of milk fat, ... 14
Sub-earth duct for curing rooms, ... 85
Sugar milk, ... 19
Sugar milk in buttermilk, ... 57
Sugar milk in cheese, ... 91
Sugar milk in condensed milk, ... 116
Sugar milk in milk, ... 20
Sugar milk in separator slime, ... 40
Sugar milk in skim milk, ... 38
Sugar milk in whey, ... 97
Sulphuric acid in Babcock test, ... 103
Sunlight, effect on germs, ... 23
Sweet-cream butter, ... 42
Swelling of cream, ... 50
Swiss cheese, ... 117

T.

Tablets, Farringtons alkaline, ... 112
Taints in milk from bacteria, ... 25
Taints in milk from food, ... 25
Taste of milk-fat, ... 14
Temperature, correction for lactometer, ... 113
Temperature, effect of, on action of rennet, ... 66
Temperature, favorable for bacteria, ... 22
Temperature for churning, ... 47
Temperature for cooking curd, ... 73
Temperature for curing cheese, ...80, 84
Temperature for ripening cream, ... 43
Temperature of milk for adding rennet, .. 70
Temperature, relation of, to ferments, .. 22
Test, Babcock, ... 100
Test, Babcock, correction of glassware, 102
Test bottle, Babcock for milk, ... 101
Test bottle, Babcock for cream, ... 107
Test bottle, Babcock for skim-milk, ... 108
Test, hot-iron, ... 74
Test, rennet, Marschall's, ... 68

Page.

Test, rennet, Monrad's, ... 67
Testing cream, ... 107
Testing milk, ... 99
Testing milk, taking samples for, ... 103
Texture of butter, ... 55
Texture of cheese, ... 87
Total solids in milk, ... 20
Tuberculosis germs in milk, ... 27
Typhoid fever germs in milk, ... 27
Tyrotoxicon, ... 26

U.

Udder cavity, germs in, ... 24
Uses of skim-milk, ... 39
Utensils, dairy, cleaning, ... 28

V.

Varieties of cheese, ... 116
Viscogen, ... 37
Viscosity of milk, ... 34
Viscosity of milk, relation of churning, .. 47
Viscosity of milk, relation of creaming, .. 34

W.

Washing butter, ... 51
Washing dairy utensils, ... 28
Water, amount of, in milk, ... 11
Water, chemistry of, ... 11
Water in butter, ... 41
Water in buttermilk, ... 57
Water in cheese, ... 98
Water in condensed milk, ... 116
Water in milk, ... 11
Water in milk of American Holderness cows, ... 12
Water in milk of Ayrshire cows, ... 12
Water in milk of Devon cows, ... 12
Water in milk of Guernsey cows, ... 12
Water in milk of Holstein cows, ... 12
Water in milk of Jersey cows, ... 12
Water in milk of Shorthorn cows, ... 12
Water in separator slime, ... 40
Water in skim-milk, ... 38
Water in whey, ... 97
Water, office of, in milk, ... 11
Whey, albumin in, ... 97
Whey, casein in, ... 97
Whey, cheese, ... 117
Whey, composition of, ... 97
Whey, dipping, ... 74
Whey, drawing, ... 74
Whey, fat in, ... 97
Whey, lactic acid in, ... 97
Whey, removing from curd, ... 74
Whey, solids in, ... 97
Whey, solids in milk, ... 91
Whey, sugar in, ... 97
Whey, testing fat, ... 108
Whey vat in relation to bacteria, ... 24
Whey, water in, ... 97
Whey, when to remove from curd, ... 74
White specks in butter, ... 44
Whole-milk cheese, standard composition for, ... 95
Wisconsin curd test, ... 64
Working butter, ... 52

Y.

Young American cheese, ... 78